Practical Stationary Engineering

WEST

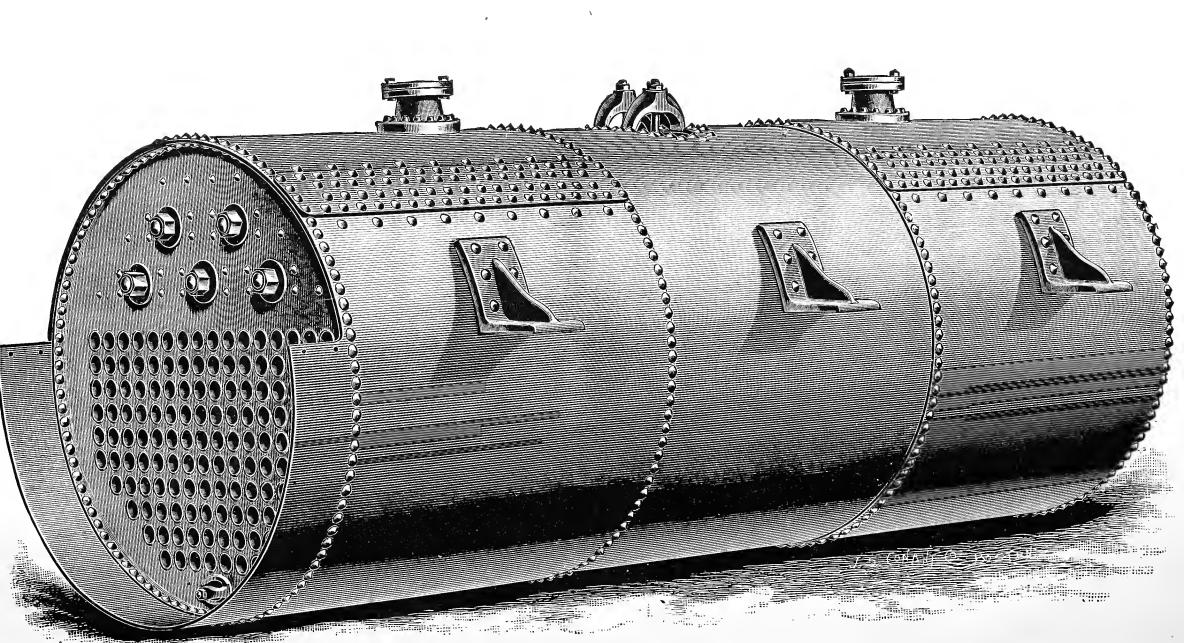

FIGURE 1.

Practical Stationary Engineering

IN FORM OF

Questions and Answers

BY

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FORMERLY

Chief Engineer Charles H. North & Co., Packers
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CONTAINING

Information relative to
Steam Boiler, Steam Boiler Accessories, Riveting, Bracing, Steam Engine Indicators, Indicator Cards, Valve Setting, Pumps, Condensers, Etc., with simple Arithmetical Rules for computations and one hundred illustrations.

PREFACE.

The author, a practical first-class licensed engineer of long and varied experience, has for some time felt the need of a clear and concise work by which the average fireman or engineer may perfect himself in his chosen profession, as well as prepare for the necessary examinations essential to his advancement to higher grades. In perfecting his book, he has endeavored to make it as simple as possible, and, wherever practical, has eliminated all traces of technicality and formula. In place of the former he has given the common names and phrases, while the latter is substituted for simple arithmetical rules that can be easily worked out by any one understanding addition, subtraction, multiplication, and division. During his thirty years' experience as fireman, engineer, and mechanical superintendent, together with the experience obtained as instructor and manager of engineering schools, he has had the opportunity to become acquainted with the requirements of the fireman and engineer. He has carefully observed and noted the various stumbling-blocks so likely to confuse not only the beginner, but also the man who in every-day practice finds some point upon which he desires to be enlightened.

The author wishes to state that this work cannot be read as a story, but requires careful study and its answers committed to memory, to be expressed in the student's own language after he has clearly understood the points desired to be brought out by the writer.

To the man striving for a fireman's license he would advise thoroughly mastering the questions and answers pertaining to boilers and boiler accessories.

For the third-class engineer he advises study on subjects previously mentioned, together with the text on engines and valve setting for the simple slide valve and riding cut-off valve.

For a second-class engineer he advises study on all the subjects treated in the works, with particular attention to the text on indicator diagrams.

For the first-class engineer, he must be thoroughly acquainted and able to answer all questions contained in this book. While he may never be called upon to answer more than one-half, it is safe to know them all, as no hard-and-fast rules are followed by the inspectors at examination.

The difference between the first-class grade and the second-class grade is a more thorough and stringent examination of the first-class.

The work fully covers all examination questions liable to be asked the applicants by the State Examining Board.

The writer will be well repaid if through this volume the student finds means of improving his condition or of advancement to a higher grade.

To the following-mentioned manufacturing companies he desires that credit be given for supplying information and electrotypes relative to their product: American Steam Gage Company, Boston, Mass.; The Locomotive: Hartford Steam Boiler Inspection Company; Mason Regulator Company, Boston, Mass; Putnam Machine Company, Fitchburg, Mass.; C. H. Brown & Co., Fitchburg, Mass.

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CHAPTER I.

BOILERS.

Steam boilers are made in a variety of shapes, according to the types, uses, and conditions. The materials of which boilers are constructed are exposed to conditions which weaken them and shorten the life of the boiler. Among these conditions are corrosion, both external and internal, high pressure, and expansion and contraction, due to varying temperatures and pressure. Where exhaust steam returns to a boiler, oil with steam makes foam and the boiler is liable to bag.

Question.—What are the different kinds of boilers?

Answer.—Stationary, marine, locomotive.

What are the different styles of boilers?

Return tubular, marine, locomotive, upright, flue, and water tube.

What is a steam boiler?

A steam boiler is a closed vessel in which steam is generated for power or heating purposes.

What is a fire-tube boiler?

Any boiler where the fire passes through the tubes.

Describe a return tubular boiler.

A return tubular boiler is a fire-tube boiler where the fire passes over the bridge wall under the boiler, returning through the tubes into the front connection and then to the chimney.

What is the dry sheet?

The dry sheet is in the front part of the boiler, is a part of the boiler shell, and its object is to form the bottom of the smoke-box.

What is the usual diameter of return tubular boilers?

Standard makes are from 24 to 72 inches.

What is the usual length?

Standard makes are three times diameter.

Where are the grates?

The grates are at the front end of the boiler, and are about thirty inches from the shell.

Are grates level?

The grates pitch to the bridge wall 3 inches.

How are they supported?

By bearer bars. These bars are supported by the brick-work.

What are the grates made of?

The grates are made of cast iron.

What kind of joints are used in a boiler?

The boiler plate has lap and butt joints. These joints or seams may be either single or double or triple riveted. The seam running lengthwise is the longitudinal seam. The seam around the boiler is the girth seam, and is single riveted.

What is the usual size of tubes in a boiler?

In a return tubular boiler they are from 2 to 4 inches diameter.

The tube sheets are drilled, reamed, and the burrs removed. The tubes are then fastened into the plate by expanding, which is done with a roller expander. The tube ends are then beaded or turned over, forming a tight joint between plate and the tube.

Which way do the heads flange?

The front head flanges out, so that it can be caulked. The back head flanges in.

How are the heads protected?

The back head is protected by water. The front head is protected by brick-work.

How is the dry sheet protected?

The dry sheet and rivets are protected by brick-work resting on the arch of the fire-door. The brick-work goes under the boiler far enough to cover the first head row of rivets.

What is the difference between a flush front and an overhanging front?

The front of a boiler may be a flush front or an overhanging front. The flush front must be protected by the brick-work. The overhanging front is used so that the dry sheet and the rivets need no protection from the fire, as it is outside of the furnace.

In an overhanging front boiler what protects the iron front?

An 8-inch wall over the arch.

What is the difference between a lap joint and butt joint?

The lap joint is the lapping of two ends one over the other. The butt joint is the ends coming together, and a cover plate on the inside and one on the outside.

Which is the wider cover plate?

The inner plate.

Why is the inner cover plate the widest?

To give strength to the caulking edge.

Why is the girt seam single riveted?

Because there is not so much surface on the heads of the boiler for the steam as on the sides.

How are the tubes measured, inside or outside?

Always on the outside.

If tube ends leak, what should be done?

Expand and bead them over.

Is there any difference in the thickness of the shell and heads of the boiler?

In a return tubular boiler the heads are $\frac{1}{16}$ thicker than

the shell in order to give it strength, on account of the many holes, for the tubes.

If boiler was lying on the ground, could you tell which was the head?

Yes, by the flange and dry sheet.

How is the dry sheet protected?

In a flush-front boiler the brick-work must go back far enough to cover up the rivets to keep them from burning out.

Is the dry sheet a separate part of the boiler?

No, it is a part of the shell.

With an overhanging front boiler, how is the cast-iron front protected?

By two rows of brick built over the arch of the door. This is to keep the intense heat from cracking the boiler front.

How is the boiler set?

The boiler has two walls on the sides and rear end, with an air-space of about three inches. This space is to allow for expansion of the inner wall without injuring the outer wall, and is to prevent radiation of heat. Bricks project across the air-space, but do not go into the outer wall. This is to keep the inner wall from collapsing.

How thick are the walls?

The wall at the grate line, according to the Hartford setting, is 30 inches, the outer wall is 12 inches, the inner wall is 16 inches with a 2-inch air-space.

How thick is the bridge wall?

At the base 28 inches.

How far from the shell?

From 8 to 12 inches.

Where is the bridge wall?

At the back of the grates.

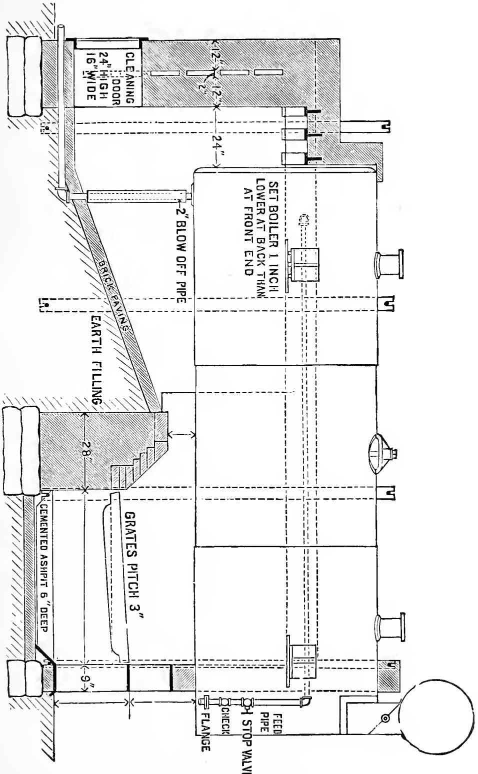

CLEANING DOOR 24" HIGH 16" WIDE
12"
12"
2"
24"
SET BOILER 1 INCH LOWER AT BACK THAN AT FRONT END
2" BLOW OFF PIPE
BRICK PAVING
EARTH FILLING
28"
GRATES PITCH 3"
CEMENTED ASHPIT 6" DEEP
9"
FEED PIPE
STOP VALVE
CHECK
FLANGE

FIGURE 2.

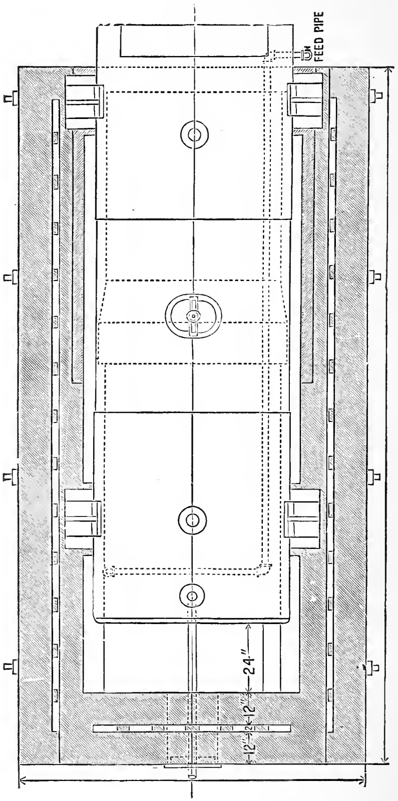


FIGURE 3.

What is its use?

To keep the coal on the grates and keep the flame up against the boiler shell.

Where is the back connection?

The back connection is at the back end of the boiler and the brick-work.

Where is the closing-in line in the back connection?

The closing-in line is about three inches above the upper

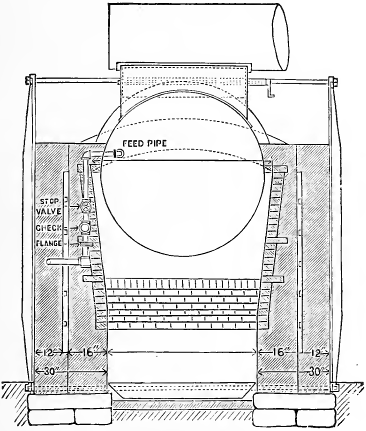


FIGURE 4.

row of tubes. There is $\frac{1}{2}$ inch space left for the expansion of the boiler.

What supports the brick-work over the back connection?

There are iron bars reaching from side to side. The bricks rest on these.

Where is the blow-off pipe?

A blow-off pipe should connect with the shell at the bottom near the rear head. The shell at this point is reinforced by

means of a metal plate, $\frac{1}{2}$ to $\frac{5}{8}$ of an inch thick, riveted to shell.

Of what use is the blow-off pipe?

The blow-off pipe is to drain the boiler.

Where does the blow-off pipe lead to?

The blow-off pipe leads out of doors or into a blow-off tank.

When is it used?

Every morning. This is because the sediment has a chance to settle to the bottom of the boiler over night.

How large is the blow-off pipe?

Usually 2 inches.

What is a blow-off tank?

A blow-off tank is about five feet deep and two and one-half to three feet in diameter, having a manhole in the top, and is used to blow off the boiler in.

What pipes lead into the blow-off tank?

The blow-off pipe from the boiler and all drips, and there is an overflow and a vapor pipe. The overflow leads to the sewer: the vapor pipe is to relieve the tank of pressure.

When do you use a reinforcing piece on a boiler?

When the pipe is over $1\frac{1}{2}$ inches in diameter, a piece of boiler plate is riveted to the shell. This is to give strength and a better hold to the threads.

What is the best kind of a blow-off valve?

Plug cock is the best kind of blow-off valve, as a globe valve would fill up with sediment and leak. This valve should be opened slowly and closed slowly. Stopping the flow of water quickly might burst the pipe at the elbow; and, if blow-off pipe should burst, immediately disconnect steam connection to other boilers, to prevent steam leaving these boilers.

What kind of brick is used in the settings?

Hard-burnt brick except around the fire-box, which is of fire-brick. These brick extend up to the closing-in line and beyond the bridge wall (every fifth course being a course of headers), which extends back to the rear of the bridge wall, and the wall is closed in upon the shell at a point one course of brick below the lugs. The face of the front wall, and both the face and top of the bridge wall, are lined with one course of fire-brick laid as headers. The rear wall of the setting is also lined with one course of fire-brick.

What support the brick over the back connection?

The brick over the back connection are supported either flat cast-iron plates or by arch bars; and these last are lined with fire-brick, which are held by projections on the ends of the bars.

What care is taken in setting the boiler?

In setting the boiler, great care should be taken that the weight of the boiler rests on the brackets, or lugs, and in no case on the cast-iron front. The brackets are so placed that their bearing surface are 3 or 4 inches above the centre of the boiler. Boilers up to 16 feet in length are furnished with 4 brackets: those of greater length have 6 brackets.

What do the brackets rest on?

The front bracket should rest on the wall plate, and the others rest upon rolls. This is to provide for the expansion. All boilers expand when heated.

Where are the fusible plugs placed?

Fusible plugs are placed in return tubular boilers 3 inches above the upper row of tubes, in the back head.

For what purpose?

For a safeguard against overheating, should the water get low.

Of what is the fusible plug made?

The fusible plug is made of brass. The plug consists of an alloy of tin, lead, and bismuth, which melts at a low temperature (360° F.). So long as the plug is covered with water, the plug is kept from melting, water taking out all the heat that the fire puts in; but, should the water sink low enough to uncover the plug, it quickly melts, and allows the steam and water to rush into the furnace, thus relieving the pressure.

What are the differences in fusible plugs?

Inside and outside; you can tell them by the shape of the cone-shape filling: the largest part is towards the pressure.

Where is the combustion chamber?

Back of the bridge wall.

Does steam protect the fusible plug?

Steam throws off heat instead of absorbing it.

Water being as hot as the steam, why does not the fusible plug melt?

The water absorbs all of the heat that the fire can put into the fusible plug.

How are boilers kept clean?

By putting in soda ash. Then the boiler should be frequently blown out, as the soda softens the scale.

What kind of valves are put on the blow-off pipe?

A plug cock is the best kind of blow-off valve, as a globe valve is liable to get stopped up with sediment and leak.

How should valves be opened when the boiler is under pressure?

All valves should be opened very slowly.

Does the boiler set level?

The boiler pitches to the rear about one inch.

Where is the closing-in line of the boiler?

Where the brick-work touches the boiler and always below the water line.

How do you get into the back connection?

Through the back-connection door.

Can you see the whole back head?

No, you can see the fusible plug, the ends of the tubes, blow-off pipe, hand-hole plate.

Where are the hand-hole plates, and what are they for?

The hand-hole plates are at each end of the boiler below the tubes. They are to clean out the boiler.

What shape are they?

The hand-hole plates are oval, so they can be removed.

Where is the manhole cover, and how large is it?

The manhole cover is on top of the boiler, 11 × 15 inches.

Which dimension lengthways?

The short dimension, or 11 inches.

What is the manhole frame made of?

The manhole frame is made of pressed steel.

Where are the nozzles, and what are they made of?

The nozzles are on top of the boiler. They are made of cast steel.

What does the furnace mouth consist of?

The furnace mouth consists of a dead plate, two cheeks, and arch.

Where is the feed-pipe?

The feed-pipe runs along the front of the boiler above the fire-doors up and through the dry sheet, enters the boiler above the tubes, runs along to the rear, crosses, and discharges the water between the tubes and shell.

How are boilers fed with water?

Boilers are fed with a pump, inspirator, or by city pressure.

Can you feed one boiler from another?

One boiler can be fed by closing the main blow-off and opening blow-off on each boiler, then water will equalize in each boiler.

Where are the nozzles, and what are they for?

There are two nozzles on a boiler. The front nozzle, steam connection, should be made for the engine or building. The rear nozzle is for the safety-valve. When but one nozzle, steam is taken from one side of safety-valve, the opposite side being used when the safety-valve opens to relieve the boiler pressure.

How is the steam connection made to the boiler?

The steam connection is made with a flange joint.

Of what are the nozzles made?

The nozzles are made of cast steel, and riveted to the shell.

What are the different kinds of safety-valves?

There are two kinds, lever and ball, and spring.

What are they for?

The object of the safety-valve is to prevent the pressure going higher than a certain point. They should open when the pressure reaches that number of pounds, and then blow from the boiler all the steam the boiler can make without increasing the pressure.

How do you increase the pressure?

With the lever-and-ball type there is a ball which you move out toward the end of the lever, increasing the pressure; and moving in decreases the pressure. The pop, or spring, valve, tightening down on the spring, will give more pressure. This is adjusted by a ring inside of safety-valve. By removing a set screw on the side of valve, this ring can be reached. By turning up, blows back more; by lowering, blows back less.

What care do you give a safety-valve?

Safety-valves should be tested by lifting the lever of the valve or pulling down on the lever of the pop-valve, and steam will blow out.

Should there be any valves between the safety-valve and the boiler?

There should be no valve connected with the safety-valve whatever.

Will the safety-valve close at the same pressure that it opens?

Pop-valves do not close at same pressure they open at, blowing back several pounds before closing.

If safety-valves stick and pressure runs too high, what do you do?

If pressure runs too high, open fire-doors and close ash-pit doors, cover fires heavy with coal, open valve slowly, that will release boiler of steam pressure until pressure comes down to where it should blow at, then try the safety-valve.

Would you start the pump, if not running?

I would not start the pump nor open the safety-valve.

If you had a battery of boilers and the safety-valve should stick on one boiler, would the pressure rise in that boiler?

Pressure could not rise higher on that boiler when connected with other boilers, because pressure would equalize through the main steam pipe.

How do you test a safety-valve?

In testing a safety-valve to see if large enough, it may be made by shutting all steam valves and see if pressure does not go above blowing point.

Are there any valves on the feed-pipe?

On each feed-pipe is a check-valve to prevent the water backing out of the boiler.

Are there any other valves on the feed-pipe?

There is a stop-valve between the check-valve and the boiler.

In a battery of boilers, is there more than one check-valve?

Each boiler has a check-valve and a stop-valve.

What is the stop-valve for?

The stop is to regulate the water-feed, and is closed if the check-valve needs to be repaired.

If check-valve should leak, would the water leave the boiler?

Water could not pass beyond the pump.

What kind of a pipe is best for a feed-pipe?

A brass pipe is best because it does not corrode.

Can you feed one boiler from another?

Yes, by closing main blow-off. Open the blow-off to each boiler, the water will equalize in all of the boilers.

What makes a check-valve rattle?

When the pump is not pumping steady.

How would you know if the pump was pumping steady?

By opening the pet cock on the air chamber, you would get a steady flow of water. If the pump was not pumping steady, you would get water and then steam, and you might hear the check-valve rattle.

What is a fire-box boiler?

A fire-box boiler is where the fire is on the inside, like a water-leg boiler, a common upright, "Manning" and "Deane" boilers, also locomotive boilers.

Describe a return tubular boiler.

Return tubular boilers are externally fired, the fire passing over the bridge wall, under the boiler, returning into the tubes to the uptake or smoke-box. The diameter of the boiler varies from 36 inches up to 72 inches, and the length is three times the diameter. The joints are single or double

riveted. The seam around the boiler is usually single riveted. The tubes are about three inches in diameter, expanded into the head and beaded over. In the front end of the boiler the dry sheet forms the bottom of the smoke-box. It is a part of the boiler shell, and is protected from the fire by brick-work beneath it. This brick-work extends under the boiler just beyond the first row of rivets. If the brick-work falls down, the dry sheet and rivets would be burned. In a flush-front boiler the dry sheet must be continually protected. In an overhanging front the sheet is outside, and overhangs the iron front. The dry sheet is outside of the setting, and needs no special protection from the fire. This is why it is used.

The walls of the back setting are about two feet thick. The wall consists of two walls, with an air-space between each wall. The boiler is held up in the brick-work by cast-iron lugs riveted to the shell, two on each side. These lugs rest on cast-iron plates in the brick-work. The closing-in line is where the brick-work closes in to the boiler, half-way up each side. If the fire went clear around the shell, the upper part would burn out where the steam-space is. The grates are at the front end, about two feet below the bottom of the boiler. They are of cast iron. The bridge wall is back of the grates. It is to keep the flame against the shell and prevent coal falling over into the combustion chamber. The combustion chamber is back of the bridge wall. The back connection is between the end of boiler and the back brick wall. You can get into it through a door at the back end of the boiler or over the bridge wall. You cannot see the whole of the boiler head, as it is bricked in from 2 to 3 inches above the tubes. This brick-work is put in to protect the end of the boiler at the steam-space. The boiler has a

cast-iron front to which the furnace doors, ash-pit doors, and tube doors are attached.

What can you see in the back connection?

In the back connection can be seen blow-off pipe, tube ends, fusible plug, and hand-hole plates.

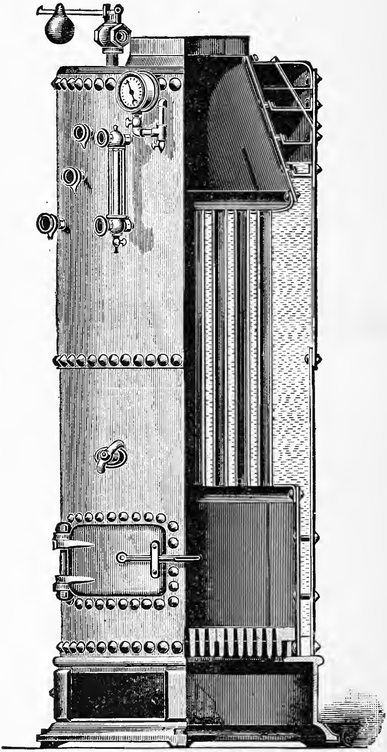


FIGURE 5.

What are tubes made of?

Boiler tubes are made of steel or wrought iron, most commonly of charcoal iron, and lap welded. In the formation of the lap the plate is upset, then bent around until the thickened edges lap sufficiently. It is then heated successively, about eight inches at a time, and welded over a mandrel. Tubes are measured by their outside diameters, and are usually true to gauge, so that holes for them may be bored without taking measurements from the tubes.

UPRIGHT BOILERS.

What is an upright boiler?

An upright boiler is a fire-tube boiler. It has a fire built in a fire-box inside the boiler. The grates are at the bottom of the boiler, on an iron ring. Around the fire is an internal shell, which forms a space, or water leg, between the fire and the outer shell. This space is 3 inches or more, and is always filled with water. Directly over the fire is a tube sheet, filled with tubes 2 inches in diameter. These tubes run to the top of the boiler, into the upper tube sheet. The smoke then passes into a smoke bonnet and flue. The inner shell extends from the mud ring to the lower tube sheet.

What is a mud ring?

The mud ring is a cast-iron ring which forms the space between the outer and inner shell at the bottom of the boiler.

Are there any braces in an upright boiler?

There are stay-bolts running from the outside shell to the inside shell through the water leg. These bolts are threaded their entire length, and are screwed in, then cold-headed: these are to prevent the inner shell from collapsing.

How is the water leg cleaned?

There are two or more hand-hole plates at the bottom of the water leg, and three on a level with the lower tube sheet.

Where is the feed-pipe?

The feed-pipe enters at the lower part of the water leg. These boilers are carried about three-quarters full of water.

Where is the steam pipe?

The steam pipe is taken from the top head.

Where is the blow-off pipe?

The blow-off pipe is in the bottom of the water leg.

Where is the fusible plug?

The fusible plug is generally found in the lower tube sheet, but should be placed about seven inches below the water glass in a tube. This plug is put in through a hole in the outside shell with a socket wrench.

Stay-bolts are put in water legs of upright or locomotive boilers, to stay any flat or round surfaces from collapsing.

They are about $\frac{3}{4}$-inch diameter. A $\frac{1}{8}$-inch hole is sometimes drilled in the outer end, just beyond the shell, to show if stay should break. Stay-bolts get corroded, and break near the outer shell. They are 5 to 10 inches apart, according to pressure carried.

Upright boilers can bag on the lower tube sheet, and on the inside sheet between the stay-bolts.

To inspect an upright boiler, look for leaks on tube ends top and bottom, for cracks between tubes on tube sheet, for leaks at seams. Sound the stay-bolts with a hammer to see if broken. Look for corrosion around grates on inside shell, and see if not blistered or bagged.

Some upright boilers have the head submerged beneath the water.

Are the heads of a boiler as thick as the shell?

The head or tube sheet is usually made $\frac{1}{16}$ inch thicker

than the shell plate. This is done for additional stiffness and increase of strength, the plates being weakened by drilling the holes for the ends of the tubes. Tubes should be arranged in vertical and horizontal rows, if possible, in order that the rising bubbles of steam may not be hindered. The tubes should be from $\frac{3}{4}$ to 1 inch apart, and the bottom tubes 6 inches from the shell.

How do you brace the head of a boiler?

The bracing of the heads of return tubular stationary boilers, when the diameter is less than 60 inches, is accomplished by using diagonal braces, one end of each being riveted to the shell and the other bolted to a tee-bar which is fastened by rivets to the head. The tee-bars are laid out according to the customary practice.

How do you brace the head of a 60-inch boiler?

When the diameter is 60 inches or over, through bolts are employed, running from head to head, with two nuts on each end, one on the outside and one inside the plate. At the points where the bolts pass through the plate, the head is stiffened by channel iron bars, one continuous bar being used for each horizontal row of bolts. In some cases a combination of through bolts and diagonal braces is employed.

How do you attach pipe to the outside shell?

When pipes $1\frac{1}{2}$ inches are attached to the outside shell of the boiler, the metal is thickened by a reinforcing plate, which is secured by rivets.

For main connection of steam pipe and safety-valve, nozzles are provided, which are riveted to the shell, the face of the outer flange being turned, and the flange itself drilled for the reception of bolts.

An ash-cleaning door is provided in the rear wall.

The upper shell of the boiler may be covered with one course of fire-brick laid on edge or with non-conducting covering.

What are the different kinds of braces in a boiler?

There is the radial brace, crowfoot, through brace, and gusset brace.

Are through bolts or braces the same diameter throughout?

Through braces are always larger at the ends, the depth of the threads, so that the strength will be equal throughout.

What does the number of braces depend upon?

The number of braces depends upon the area to be braced, steam pressure carried, size of braces.

What is the size of through braces?

Usually 1 inch to $1\frac{3}{4}$.

What is a gusset stay?

This stay consists of a wrought-iron or steel plate secured to the heads and shell by either angle or T iron. It is much used for staying the heads of internally fired boilers of the Lancashire and Galloway type.

The method in which the gusset plate is flanged to one side and the angle iron riveted to the other. Gusset stays are placed radially in a boiler, the largest one in the centre, and smaller ones to the right and left of it.

What does the through brace pass through before going through the head?

There is a channel iron or angle irons riveted to the head on the inside. This is to give strength to the heads which the through braces pass through.

What is a palm brace?

The middle brace would come under the manhole; and, to prevent this, one end is radial. The end that comes through the head is fastened like a through brace, and the other end

is flattened and riveted to the shell with 3 rivets near the manhole. This is called a "palm brace."

Water Column.

What is the water column for?

The water column is used to ascertain the height of the water in the boiler.

Where is it placed?

The water column is placed at front end of the boiler, connected to the top and bottom by pipes. The lower nut on the gauge glass should be 3 inches above the upper row of tubes. This you can tell by opening the tube-sheet door and sighting across.

What if you find it is too low?

Would carry water proportionately as high in the glass.

If glass should break, what valve would you close first?

If the gauge glass should break, would close the lower valve first, as the water would flow out to that point. This gauge is liable to break at all times. For this reason it is essential, when leaving the boiler at night, to close the gauge-glass valves. You should blow this out every morning, top and bottom, before starting up.

If you close the top valve on the gauge, what is the effect on the water?

The water will rise to top almost instantly.

What if you close the bottom valve?

Water will remain where it is.

If you shut the top valve and the water does not rise, what is the reason?

The lower valve may be closed or the valve may leak.

If the glass is full of water and the gauge-cocks do not show water, what is the reason?

This shows that it is closed on top.

If at any time you could not get steam or water from the column?

This shows that both valves are closed or stopped up.

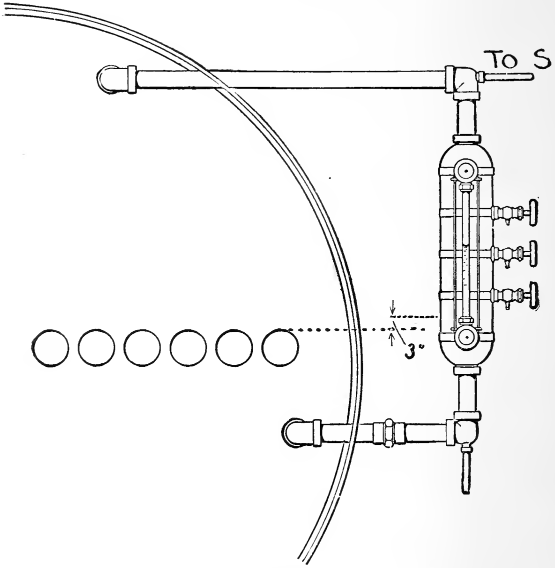


FIGURE 6.

Suppose some morning we see water in the glass, we try the cocks and get no water, what is the reason?

This shows that there is a vacuum in the boiler. Open gauge-cocks above water line, let air in, water will flow out.

How can you tell if the gauge glass and water column is all right by looking at it?

You could see a slight motion of the water in the glass.

What would you do if you found the water too low?

Bank fires heavy, close ash-pit doors, cool boiler off.

Would you start the pump at that time?

No, it would be very dangerous to do so before the boiler was cool.

Would you lift the safety-valve?

No, that would be dangerous. The water might flash into steam and cause the boiler to explode.

BABCOCK AND WILCOX BOILER.

These boilers are composed of lap-welded wrought-iron tubes, placed in an inclined position and connected with each other, also with a horizontal steam and water drum by vertical passage at each end, while a mud drum is connected to the rear and lowest point in the boiler.

The tube ends are expanded into vertical headers made of cast steel. The vertical headers are connected to the steam drum by nipples, one header for each vertical row of tubes, and are of such form that the tubes are staggered, or so placed that each row comes over the spaces in the previous row.

The holes are accurately sized, made tapering, and the tubes fixed therein by an expander. The section thus formed is connected with the drum, and with the mud drum also by short nipples expanded into the bored holes. The openings for cleaning opposite the ends of each tube are closed by hand-hole plates. The joints are made in the most thorough manner by milling the surfaces to accurate metallic contact,

and are held in place by wrought-iron forged clamps and bolts.

The steam and water drum is made of flanged steel of extra thickness and double riveted. They can be made for any desired pressure, and are always tested at 50 per cent. above the pressure for which they are constructed. The mud drum is of cast iron, as the best material to withstand corrosion. In the mud drum are three common hand-hole plates for cleaning.

Why is the water-tube boiler used?

The water-tube boiler is used for additional safety at high pressure and for quick steaming. Only a small part can burst at a time.

Are there any braces in a Babcock and Wilcox boiler?

There are no braces. The forged-steel drumheads are spherical, therefore do not need bracing.

Where is the manhole plate?

Manhole is in the front head.

What can you see inside of the steam drum?

You can see the feed-pipe, the dry pipe, the baffle plate, and a pipe from the lower connection of the water column and the fusible plug which is about four inches up on the side of the drum over the fires.

What is a water-tube boiler?

Water in the tubes and the fire outside.

What is the method of supporting the boiler?

The usual method is to hang the boiler from wrought-iron girders resting on vertical iron columns. The brick-work is not depended upon as a means of support. The bridge wall is built up to the bottom row of tubes. Another fire-brick wall is built between the top row of tubes and the drum. These walls and baffle plates force the hot furnace

gases to follow a zigzag path back and forth between the tubes. The gases finally pass through the opening in the rear of the wall, into the chimney flue.

Where is the water column?

The water column is at the front of the steam drum. In the lower connection there is a pipe extending into the drum about four feet, in the upper connection the pipe leads into the dry pipe.

Where is the blow-off pipe?

The blow-off pipe is in the mud drum.

Where is the feed-pipe?

The feed-pipe is in the steam drum, front or rear head.

What is the standard evaporation per horse power?

The standard of steam boiler horse power as adopted by the American Society of Mechanical Engineers rates a commercial horse power on an evaporation of 30 pounds of water per hour from a feed-water temperature of 100° F. into steam at 70 pounds' gauge pressure.

An approximate list of square feet of heating surface per horse power for difference in styles of boilers.

Type of Boiler.	*Square Feet Heating Surface for 1 H. P.*	*Coal per Square Feet H. P. per Hour.*	*Relative Economy.*
Water tube	10 to 12	3	100
Tubular	10 to 12	.25	.91
Flue	8 to 12	.4	.79
Plain cylinder	6 to 10	.5	.69
Locomotive	12 to 16	.275	.85
Vertical tubular	15 to 20	.25	.80

HEINE BOILER.

Inside of the shell is located the mud drum, 2 or 3 inches above the bottom of the shell.

It is thus completely immersed in the hottest water in the boiler.

It is of oval section, slightly smaller than the manhole, made of strong sheet iron with cast-iron heads.

It is entirely enclosed except about eighteen inches of its upper portion at the forward end, which is cut away nearly parallel to the water line.

The feed-pipe enters it through a loose joint in front. The blow-off pipe is screwed tightly into its rear head, and passes by a steam-tight joint through the rear head of the shell.

Just under the steam nozzle is placed a dry pipe.

A deflection plate extends from the front head of the shell, inclined upwards, to some distance beyond the mouth or throat of the front water leg. It will be noted that the throat of each water leg is large enough to be the practical equivalent of the total tube area, and just where it joins the shell it increases gradually in width by double the radius of the flange.

In setting the boiler, place its front water leg firmly on a set of strong cast-iron columns, bolted and braced together by the door-frames, dead plate, etc., and forming the fire front. This is the fixed end. The rear water leg rests on rollers which are free to move on cast-iron plates firmly set in the masonry of the low and solid rear wall.

Wherever the brick-work closes into the boiler, broad joints are left, which are filled in with tow saturated with fire clay,

or pliable material. Thus the boiler and its walls are each free to move separately during expansion or contraction.

On the lower and between the upper tubes are placed light fire-brick tiles. The lower tier extends from the front water leg to within a few feet of the rear one, leaving there an upward passage across the rear end of the tubes for the flame. The upper tier closes into the rear water leg and extends forward to within a few feet of the front one, thus leaving the opening for the gases in front.

The bridge wall is hollow, and has small slotted openings in the rear to deliver hot air into the half-consumed gases which roll over the bridge wall into the combustion chamber. It receives its air from channels in the hollow side walls.

STEAM GAUGE.

What is the steam gauge for?

Steam gauge indicates the pressure of the steam contained in the boiler. The most common form is the Bourdon pressure gauge. It consists of a tube, of elliptical cross-section, which is filled with water and connected at end with a pipe leading to the boiler. The other end is attached to a link, which in turn is connected with a sector. This rack gears with a pinion to which is attached the index pointer. When water in the elliptical tube is subjected to pressure, the tube straightens out, the movement of the free end is transmitted to the pointer by the link, and the pressure is recorded on the graduated dial.

In connecting up the steam gauge, place a coil or bend in pipe below the gauge. This fills with water from condensed steam. This is to protect the gauge from heat, which protects the spring from being injured by the heat of the steam.

Where is it placed?

It can be placed where one may wish, sometimes on the water column. If it is above the boiler and steam has to hold up a column of water, it will not register as much as the boiler

FIGURE 7.

SHOWING SOME OF THE AMERICAN STEAM GAGE AND VALVE COMPANY'S GAUGES.

pressure by 1 pound for every 2 feet of water supported. If gauge is below the steam pipe, it will register more by 1 pound for every 2 feet of water head.

If gauge was placed on the water column and you should close top valve, would it register?

Steam gauge would still register, getting its pressure from the lower connection.

What is meant by setting the hand on the steam gauge at zero?

This means that the gauge is set at atmospheric pressure, 14.7 pounds.

How is a steam gauge tested?

Steam gauges are tested by comparing with a test gauge, being connected to a small hydraulic hand pump to get the pressure.

What is inside of a steam gauge?

A hollow spring.

Can a steam gauge get out of order?

A steam gauge may not register right. First, spring might leak; second, spring might be broken; third, vacuum in the boiler, the hands resting against the pin, and the spring pulling it makes the hands slip on the spindle and causes it to register light.

If you had a high pressure of steam in the boiler and water out of sight, would it be safe to raise the safety-valve to let out the steam?

No, under no circumstance.

What might happen if you have vacuum in your boiler?

When there is vacuum in the boiler, the hand rests against pin, and the spring pulling on it makes hand slide on the spindle and causes it to register light.

How do you know if it registers correctly?

To set the gauge on the boiler, set it at zero with no pressure on the boiler. See that it agrees with the safety-valve, or set it with another gauge that is known to be right.

How do you know if the steam gauge is correct?

If the steam gauge and safety-valve do not agree, the steam gauge may be out of order.

FIRES.

What is the first duty of the fireman?

Upon going to work, he should examine the water level. The gauge-cocks should be tried: the gauge glass is not always reliable. In a battery of boilers the gauge-cocks on each boiler should be tried. Some serious explosions have resulted from the fact that the fireman only consulted the water level in the first boiler, and took it for granted that the level in the other boilers was the same.

If the water is discovered to be low, quickly cover the fires with ashes, or, if not convenient, with fresh coal. Do not turn on the feed, and do not tamper with the safety-valve or any other steam outlet.

What would be the proper method to start a fresh fire?

First cover the grate bars all over with fresh coal, then put the wood on the top of the coal. Start the fire with kindlings, leaving the furnace door open until the wood is well ablaze, then add more coal as required.

How do you bank a fire over night?

With a hoe push back the upper half of the fire, leaving the clinkers and ashes on the grate, then pull the ashes out with the hoe, and then cover with fresh coal, leaving part of the grates bare.

How do you clean a soft-coal fire?

Let one side burn down, build up the other side, pull the burnt side out. Then throw over the good fire onto the clean grates with slice bar or a hoe, and build up that side,

allowing the other to burn down, then pull second side, and spread the fire over evenly.

How do you clean a hard-coal fire?

Shove good coal back to bridge wall and pull out ashes and clinkers at front. Pull good coal forward and pull clinkers over the fire from the back.

Spread over evenly. Soft-coal fires may be broken up considerably with a slice bar, but hard coal cannot be broken up, but fires are kept clean by running slice bar underneath it. Before cleaning, see that there is plenty of water in the boiler and steam pressure is high, so you will not have to pump water in the boiler immediately after cleaning fires.

The reason being that having the fire-doors open, reducing the body of fire under the boiler, putting on green coal, and then being obliged to put in cold water would cause too great a drop in the pressure.

How thick are the fires?

The thickness of the fires depends on the draft. With a very heavy draft a much thicker fire must be carried. A fire too thick for the draft blows back at the fire-door. The fires vary from 7 to 15 inches in thickness. In firing, feed often and light, placing coal on the thinner spots. When draft is poor, a thinner fire must be carried. If safety-valve blows, close ash-pit door.

How do you connect boilers together?

See that the water level is the same in each boiler, and that the steam pressure is equal in each boiler. Open valve slowly.

What would you do in taking charge of a plant?

In taking a new plant, I would look over all pipes leading to and from the boiler, look over water column to see that it is in the right position, also the safety-valve.

How do you clean the tubes of a boiler?

Most common is a tight-fitting scraper on a rod, which is run through the tubes or a jet of steam blown through them. I should recommend cleaning every day. This to be done when there is little demand for steam. At noontime is best.

CORROSION.

What is corrosion?

Corrosion may be defined as the eating away or wasting of the plates, due to the chemical action of impure water. It is probably the most destructive of the various agencies which tend to shorten the life of the boiler. Corrosion is of two forms, internal and external. Internal corrosion may present itself as: 1. Uniform corrosion; 2. Pitting or honeycombing; 3. Grooving. Corrosion is a general rusting or thinning of the plates.

In cases of uniform corrosion large areas of plate are attacked and eaten away. There is no sharp line of division between the corroded part and the sound plate, and oftentimes the only way of detecting the corrosion is to drill a hole through the suspected plate and thus ascertain its thickness. Corrosion often violently attacks the stay-bolts and rivet heads.

What is pitting?

Pitting and honeycombing are readily perceived. The plates are in spots indented with holes and cavities from $\frac{1}{32}$ to $\frac{1}{4}$ inch deep.

What is grooving?

Grooving is generally caused by the buckling action of the plates when under pressure. Thus the ordinary lap joint of a boiler distorts the shell slightly from a truly cylindrical

form, and the steam pressure tends to bend the plate at the joint. This bending action is liable to start a small crack along the lap, which, being acted upon by corrosive agents in the water, soon deepens into a groove. The marks made along the seam by the sharp caulking tool, when used by careless workmen, is almost certain to lead to grooving.

What is external corrosion?

External corrosion frequently attacks boilers, particularly those set in brick-work. The causes are dampness, exposure to weather, leakage from joints, moisture arising from the waste pipes or blow-out. When leakage occurs in a joint which is hidden by the brick-work setting, the plates may be corroded very seriously without being discovered.

External corrosion should be prevented by keeping the boiler shell free from moisture and by repairing all leaks as soon as they appear.

What is the effect of oil or grease in a boiler?

Oil or grease often causes more trouble in boilers than scale or mud, and is much more difficult to remove, as it cannot be blown off. It requires special care where a part or the whole of the feed water comes from condensers or from heating coils where exhaust steam is used.

OIL OR GREASE.

The action of oil or grease in a boiler is peculiar, but not more so than we might expect. It does not dissolve in the water nor does it decompose, neither does it remain on top of the water, but it seems to form itself into what may be described as slugs, which at first seem to be slightly lighter than the water, of such a gravity, in fact, that the circulation of the water carries them about at will. After a short season

of boiling these slugs or suspended drops seem to acquire a certain degree of stickiness, so, when they come in contact with the shell and flues of the boiler, they begin to adhere thereto. Then, under the action of heat, they begin the process of varnishing the interior of the boiler. The thinnest possible coating of this varnish is sufficient to bring about overheating of the plates, as we have found repeatedly in our experience. We emphasize the point that it is not necessary to have a coating of any appreciable thickness to cause overheating and bagging of plates and leakage at seams.

Remember this:—

The time when damage is most likely to occur is after the fires are banked, for then, the formation of steam being checked, the circulation of water stops, and the grease thus has an opportunity to settle on the bottom of the boiler and prevent contact of the water with fire sheets. Under these circumstances a very low degree of heat in the furnace is sufficient to overheat the plates to such an extent that bulging or bagging is sure to occur. When the facts are understood, it will be found quite unnecessary to attribute the damage to low water.

This is almost certain to be the result of grease in a steam boiler. It settles down on the fire sheets when the draft is closed, and the circulation of water nearly stops, and prevents contact between the plates and the water. As a consequence, the plates over the fire become overheated; and under such circumstances a very slight steam pressure is sufficient to bag the sheets. Unless the boiler is made of very good material, the plate is apt to be fractured, and explosion is likely to occur.

What is a bag?

A bag is caused by oil, grease, or any sediment collecting on

the bottom of the shell over the fire. Keeping the water away from the shell, allowing the shell to become red-hot, the internal pressure of the boiler forces the red-hot shell out, and necessarily follows a bag.

If your boiler bags, what do you do?

If the bag is small, it is heated and forced back: if the bag is large, it is cut out and a hard patch put on the inside by rivets.

BLISTERS.

What is a blister?

A blister is a separation of a thin layer of the sheet which peels off.

What do you do if boiler blisters?

Trim it off to the solid sheet; but, if large and half-way through the plate, patch it by putting a piece of boiler plate on the outside with tap-bolts. This is called a soft patch.

What is the cause of a blister?

It is caused by grease and sediment gathering on the shell. It becomes overheated, thus causing a thin layer of iron to peel off.

Why is a blister dangerous, also a scaly boiler?

A blister as well as scaly boilers will always cause an explosion by allowing the sheets to become red-hot, burnt, and also weakened. An untrue steam gauge is very dangerous, or a safety-valve that is stuck to the seat.

FOAMING.

What is foaming?

Foaming is induced in stationary boilers by a filthy condition, particularly in this to which the feed water is supplied through open heater in consequence of oil or grease, dirty water being carried over with the exhaust steam into the boiler.

What causes foaming?

Foaming is induced in all boilers by the want of proper proportions between the water space and steam room in the boiler to supply the cylinder.

How can you tell if the boiler is foaming?

You can hear the water boiling very violently, gauge-cocks will first give water and then steam, bubbles will be chasing up through the glass, the engine pounds by water getting into the cylinder of the engine.

What is the first thing to do, if boiler is foaming?

The first thing to do is to find the water level. By opening the furnace door, closing damper doors, and covering the fires with coal or ashes, and shutting the main steam valve. When water level is found, blow off through the blow-off pipe and feed fresh water at the same time, and at the first chance to shut down the boiler should be thoroughly cleaned inside.

What is priming?

Priming is due to a very large demand for steam from the boiler which lifts the water from the sheets. Priming is understood by engineers to mean the passage of water from the boiler to the steam cylinder in the shape of spray instead of vapor. It may go unseen, but it is generally made manifest by the white appearance of the steam as it issues from the exhaust pipe. Saturated steam, or steam contain-

ing water, has a white appearance, and descends in the shape of mist, while dry steam has a bluish color, and floats away in the atmosphere.

Priming is generally induced by a want of sufficient steam room in the boiler, the water being carried too high or the steam pipe being too small for the cylinder, which would cause the steam in the boiler to rush out so rapidly that every time the valve opened it would induce a disturbance, and cause the water to rush over into the cylinder with the steam.

How could a boiler foaming cause an explosion?

It raises the water from the heated sheets, the sheets become hot, the water falls back, causing it to crack, and sometimes causing an explosion.

STAYING.

When under steam, a cylindrical shell is strained by internal pressure in two directions, namely: transversely by a circumferential strain due to the pressure tending to burst the shell by enlarging its circumference, and longitudinally by the pressure on the ends. If a boiler were spherical, it would require no stays, because a sphere subjected to internal pressure tends to enlarge, but not to change its shape. All flat surfaces in boilers must be stayed, otherwise the internal pressure would bulge them out and tend to make them spherical in shape. The ends of steam drums on high-pressure water-tube boilers are often made hemispherical.

The first and most important point in staying is to have a sufficient number of stays, so that they will entirely support the plate without regard to its own stiffness. The second is to have them so placed as to present the least obstructions to a free inspection and to have them so arranged as to allow

a free circulation of water. Too much care cannot be taken in fitting stays and braces, as they are out of sight for long periods and a knowledge of their exact condition is not always easily obtained.

In the ordinary fire-tube boiler the principal surfaces stayed are the flat ends, crown sheet, flat sides of locomotive boilers, and combustion chambers of cylindrical marine boilers.

The most common and simple form of stay is a plain rod. It is used to stay the flat ends of short boilers. This stay is a plain rod passing through the steam-space, and has the ends fastened to the heads. The ends are fastened and the length adjusted in a number of ways, the simplest being nuts on both sides of the plate, and a copper washer strengthens the plate and prevents abrasion by the nut. Stays are usually from $\frac{3}{4}$ inch to $1\frac{3}{4}$ inches in diameter, and are made of wrought iron or steel, with an allowable stress of 7,000 pounds per square inch.

If a boiler is long (that is, more than 20 feet long), stays would sag in the middle and not take up the full stress in the end plates. For long boilers, gusset and diagonal stays are used.

BOILER EXPLOSIONS.

What is the cause of boiler explosions?

Boiler explosions are, in nearly all cases, due to this cause, over-pressure of steam,—either the boiler is not strong enough to safely carry its working pressure or else the pressure has been allowed to rise above the usual point by the sticking or overloading of a safety-valve; or some similar cause.

A boiler may be unfit to bear its working pressure for any of the following reasons: defect in design, defects in work-

manship or material, corrosion, wear and tear; mismanagement in operation.

Defects of workmanship and faulty material may include the careless punching and shearing of the plates, burnt and broken rivets, plates burnt or otherwise injured in flanging, bending or welding, scoring of plates along the joints by sharp caulking tools, and injury of the plates by the reckless use of the drift pin. Old plates may be injured in patching them with new plates, by the operation of removing the old rivets and putting in the new ones, and by the greater expansion and contraction of the new plate when exposed to the fire.

Overheating may be caused by incrustation, or grease may lead to the formation of pockets. When the plate is covered by a heavy scale, the heat is not carried away by the water fast enough to prevent a rise of temperature, the plate becomes red-hot and soft, and yields to the steam pressure, forming a pocket; and, if the pocket is not discovered and repaired, it stretches, until finally the material becomes too thin to withstand the steam pressure, the pocket bursts, and an explosion follows.

The strength of the shell may be weakened by corrosion, pitting, and grooving. In some boiler explosions the plates have been found wasted to little more than the thickness of paper.

Fractures which ultimately end in explosions may be produced by letting the cold feed water come directly into contact with the hot plates. The feed should be introduced into the coolest part of the boiler.

Vertical boilers hold the first place in the list of those liable to explosions. The end of the tubes and the crown sheet are very liable to corrode. The crown sheet bulges

downwards, and the reaction of the escaping steam may throw the boiler high in the air. Explosions may be the result of the collapse of the upper end of the tubes,—an event which may occur when the tubes pass up through the steam-space.

Explain the cause of a boiler exploding.

It is caused by the plates that are in contact with the fire-box or shell becoming overheated as the circulation is stopped after the steam is shut off, and as soon as the valve is opened the pressure is lessened and the water on the overheated sheet flashes into steam, and, if the boiler is not strong enough, a terrific explosion is the result.

Opening the steam valve quickly to start the engine after the circulation in the boiler has stopped and the engine has been standing for a short time causes the boiler to explode.

If you had a high pressure of steam in the boiler, and water out of sight, would it be safe to raise the safety-valve to let out the steam?

No, under no circumstance.

Why not?

It would cause the water to rise, and, when the valve closed, the water would drop back on the heated shell and be liable to explode the boiler.

INSPECTION AND TESTING BOILERS.

First let fire die down, close ash-pit doors, open fire-doors, and, when boiler ceases to make steam, disconnect from other boilers. See that water head is kept up. The boiler should be left to cool twelve hours or more before blowing off. Then remove manhole cover, also hand-hole plates. Clean off

grates, ash-pit, back connection, then wash out the boiler inside with a hose. Get inside of boiler, and look along the seams for grooving, corrosion, or incrustation. Inspect the interior for broken stays or rivets or fractured joints. The condition of the plate is determined by tapping the plate with a hammer. Any weakness will immediately show itself. See that the feed-pipe is not clogged up, also that the fusible plug is not covered with scale. Externally look out for leaks on tube ends and around the girth seam and blow-off pipe. Also look out for blisters and bagging. Examine brick-work.

It is not good practice to open tube doors till boiler has cooled off a little.

INSPIRATORS.

What is an inspirator?

An inspirator is used to feed water in a boiler. It is an auxiliary to a pump in case it fails.

Where is the steam taken from?

The steam is taken from the highest part of the boiler.

How do you start an inspirator?

To start an inspirator, all valves except the force valve and main steam valves should be open. First open steam valve until water flows out of overflow, then shut middle valve and open the force valve a quarter-way, then close overflow.

Where does the inspirator get its power?

The steam escapes from the boiler with great velocity, and, as it passes through the suction jet, draws the air along with it, and thus creates a vacuum. Atmospheric pressure forces the water up into the suction pipe across an open space, and through the force jet, the steam and water mingling, and the steam is condensed; giving up its great velocity to the water,

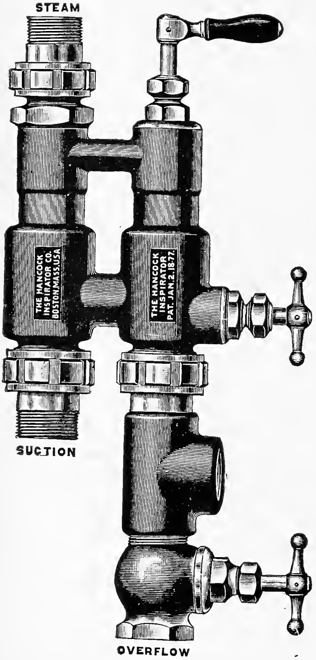


FIGURE 8.

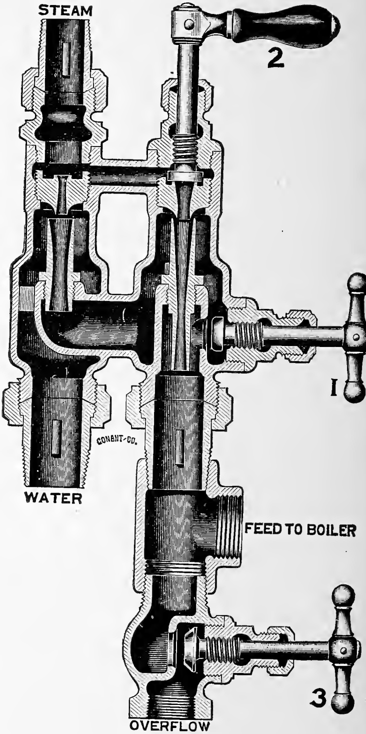


FIGURE 9.

INSPIRATORS.

is penetrated into the boiler against a higher pressure than itself.

The inspirator connection should be taken from a separate pipe from the steam-space, not from the steam pipe to engine. Inspirators will pump against one-half as much more pressure as is on boiler. A common inspirator will not pump at less than 20 pounds' pressure.

What is the difference between an inspirator and injector?

The inspirator and injector are practically the same. Injectors may be handled with one lever.

WATER PER HORSE POWER.

Average amount of water required per horse power per hour for triple expansion engines, about 14 pounds; compound engines, 18 pounds; simple condensing engines, 23 pounds; single automatic cut-off, 30 pounds; high speed, 35 pounds; and throttling side-valve engine, 45 pounds. Grate designed to burn 12 pounds of coal per hour for each square foot of grate area.

Water-heating surface for bituminous coal in horizontal tubular boilers should be from forty to forty-four times the area of the grate, and thirty-five times grate area for hard coal. In upright boilers the steam-heating surface should be included to obtain total heating surface.

To find amount water boilers must evaporate, multiply pounds of water used by engine, as given above for each horse power per hour, and by the horse power required.

To find the heating surface of the shell, multiply one-half of the circumference of boiler, in feet, by length of shell, in feet, exposed to fire.

To find the heating surface of tubes, multiply inside area in square feet of 1 foot in length of tube by the length of tube and by the number of tubes. Adding to this the exposed surface of shell and back head will give total heating surface.

To find the proper area of chimney, multiply collective area of tubes by 9, and divide by square root of height of chimney.

To find the proper height of chimney, multiply collective area of tubes by 9, and divide product by area of chimney, and square the quotient.

HEAT.

To find units of heat required to raise temperature corresponding to one gauge pressure to that of another.

Rule.—Find the square root of the gauge pressures, subtract these values, and multiply remainder by $14\frac{1}{3}$.

Example.—Find the number of heat units required to raise the pressure from 81 pounds' gauge pressure to 144 pounds' gauge pressure.

$$\begin{array}{lcr}
\sqrt{81} = 9 & 12 & 14\frac{1}{3} = 14.3 \\
\sqrt{144} = 12 & 9 & .3 \\
\cline{2-3}
 & 3 & 42.9, \text{ say 43 heat units required.}
\end{array}$$

To find units of heat required to raise temperature of 1 pound of water from 32° F. to temperature due to pressure.

Rule.—Extract square root of gauge pressure, and multiply this by $14\frac{1}{3}$. To this product add 164.

Example.—Find the number of heat units required to raise water from 32° F. to 180 pounds gauge pressure.

$$
\begin{array}{rl}
\sqrt{180}(13.41 & \\
1 & \\
\hline
23)\ 80 & \\
69 & \\
\hline
264)\ 1100 & \\
1056 & \\
\hline
2681)\ 4400 & \\
2681 & \\
\hline
\end{array}
\qquad
\begin{array}{r}
14.33 = 14\tfrac{1}{3} \\
13.41 \\
\hline
1433 \\
5732 \\
4297 \\
1433 \\
\hline
192.1453 \\
164 \\
\hline
356.14
\end{array}
$$

356.14 = number of heat units necessary.

Rule.—To find the temperature of steam, find square root of gauge pressure, and multiply this value by 14. To this product add 199.

Example.—What is the temperature of steam when the gauge registers 144 pounds' pressure?

$$
\sqrt{144} = 12 \qquad
\begin{array}{r}
12 \\
14 \\
\hline
48 \\
12 \\
\hline
168 \\
199 \\
\hline
367^\circ \text{ F.}
\end{array}
$$

What is meant by latent heat?

It is the amount of heat necessary to change liquids to gas, or solids to liquids, without increasing the temperature.

What would be an illustration of latent heat?

The melting of ice at 32° F. and the boiling of water at 212° F.

Rule.—To find the latent heat of steam, subtract ten times the square root of the gauge pressure from 977.

Example.—Find the latent heat at 144 pounds' gauge pressure.

$$\sqrt{144}=12 \qquad \begin{array}{r} 12 \\ 10 \\ \hline 120 \end{array} \qquad \begin{array}{r} 977 \\ 120 \\ \hline 857^\circ \end{array} \text{ latent heat.}$$

CHAPTER II.

SAFETY-VALVE.

Why are safety-valves placed on boilers?

To provide for the release of steam in case it should rise above the pressure representing the safe-working pressure of boiler.

What are the kinds or types of valves?

Lever, pop, or spring, and dead-weight valves.

What are the most common?

Lever and pop valves.

Describe a lever valve.

The lever valve consists of a valve proper, with stem guided in such a manner as to keep it from becoming jammed while lifted from seat. This stem is fastened usually by a pin to the lever. On one end of this lever is hung a weight, and the other pivoted to a bonnet or yoke on top of valve. This pivotal point is called the fulcrum.

Describe a pop, or spring, valve.

The pop-valve is constructed practically the same with the exception that a spring is substituted for the lever and ball, and valve is set to the required pressure by means of a screw at top by which the spring is compressed to the desired pressure at which the boiler is to blow off.

Where should a safety-valve be set in relation to the boiler?

It should be placed where there is no possible chance of cutting off communication with the boiler; that is, there should be no other valve between it and boiler. Usually,

it is placed on a flange especially provided for it directly on top of the boiler.

If valve should stick and pressure run up higher than intended to blow off, what would you do?

Close ash-pit doors, bank fires, turn steam on building slowly, or any other means to use up steam formed, but under

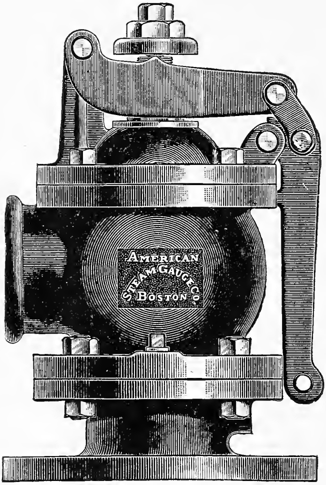


FIGURE 10.

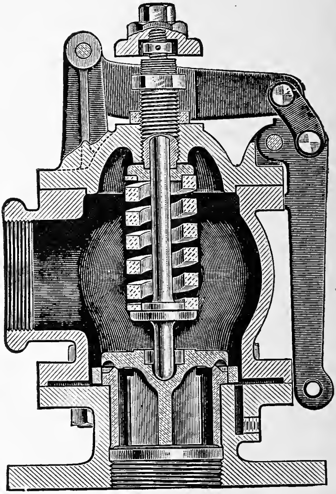


FIGURE 11.

no condition raise the safety-valve before steam had dropped to pressure intended to blow off.

Can a safety-valve be too large?

Yes, if too large, the velocity of steam through the valve may carry along with it the water in the boiler, thereby lifting the water from the sheet. Valves should be made

large enough to carry off all the steam the boiler is able to make.

How do you determine the size of valve?

The area of valve in square inches is equal to the square feet of grate surface divided by 3.

In calculating for weight of ball, length of arm, and

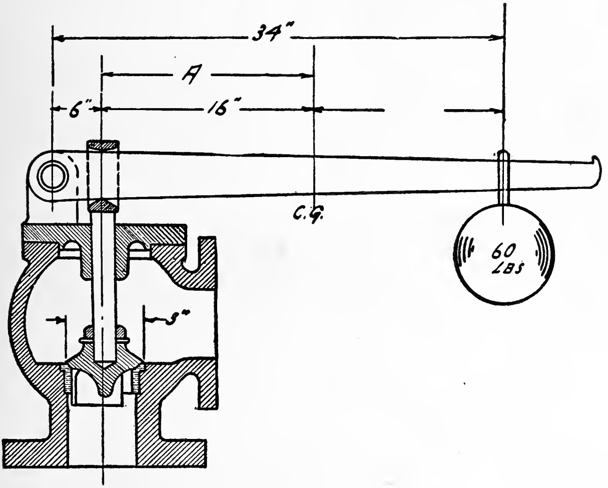


FIGURE 12.

pressure at which a valve will blow, what data must be obtained from the valve?

Area of valve, weight of lever, distance from fulcrum to centre of gravity of lever, weight of valve and stem, and distance from fulcrum to centre of valve stem.

How do you determine the centre of gravity of the lever?

Detach the lever from the valve, and move it along a knife edge until it is in balance, measure the distance "A" from fulcrum to this point, weigh the lever accurately.

The reason for this being that the weight of lever at its centre of gravity, multiplied by the distance from the fulcrum "A" and divided by the distance from fulcrum to centre of valve stem "B," is the pressure exerted on the stem of the valve by the weight of lever. Our calculations would not be correct if this value were not taken into consideration, as will be shown by study of the following examples.

To find the pressure at which a safety-valve will blow off.

Rule.—Multiply the weight of ball in pounds by the length of lever in inches, and divide the product by the distance in inches from fulcrum to centre of valve stem (call this quotient "A").

Multiply weight of lever in pounds by the distance in inches from the fulcrum to centre of gravity of lever, and divide the product by the distance in inches from fulcrum to centre of the valve stem (call this quotient "B").

Add these above values "A" and "B" to the weight of valve and stem, and divide this sum by the area of the valve in square inches.

Example.—At what pressure will a valve release the steam if the ball weighs 60 pounds, weight of lever 30 pounds, weight of valve and stem 8 pounds, length of lever 34 inches, distance from fulcrum to centre of gravity of lever 16 inches, distance from valve centre to fulcrum 6 inches, diameter of valve 3 inches?

60 = weight of ball.
34 = length of lever.
240
180

distance from fulcrum to centre valve = 6)2040(340 lbs. = the effect of the ball at the valve stem.
18
24
24

30 = weight of lever.
16 = fulcrum to centre gravity of lever.
180
30

distance from fulcrum to centre valve = 6)480(80 lbs. = effect of weight of lever at valve stem.
48

340 = lbs. due to ball.
80 = lbs. due to lever.
8 = lbs. weight of valve and stem.
428 = total pressure downward at valve stem.

3-inch diameter valve, $3 \times 3 = 9$ .7854
9
7.0686, say 7.07 square inches.

area of valve = 7.07)428.00(60.53 lbs. = pressure at which valve will blow off.
4242
3800
3535
2650
2121

To find distance from fulcrum to centre of ball.

Rule.—Multiply the area of valve in square inches by the blow-off pressure, and from this product subtract the weight of valve and stem (call this value "A").

Multiply the weight of lever in pounds by the distance in inches from the fulcrum to centre of gravity, and divide this product by the distance from fulcrum to centre of valve stem (call this value "B").

Subtract "B" from "A," and multiply the remainder by the distance from fulcrum to valve stem. Divide this last result by the weight of ball.

Example.—In the preceding example suppose we wish to have the valve blow off at 55 pounds, how far from fulcrum must weight be placed?

7.07 = area of valve.
55 = pressure to blow off at.
3535
3535
388.85 = pressure on valve.
8.00 = weight of valve and stem.
380.85 = pressure on valve.

30 = lbs. weight lever.
16 = distance from fulcrum to centre of gravity.
180
30
distance from fulcrum to centre valve = 6)480(80 = lbs. effect at valve of stem of weight of lever.
48

380.85 = pressure on valve.
80.00 = effect of valve.
300.85 = weight for ball to balance.
6 = distance from fulcrum to valve stem.
1805.10

weight of ball = 60)1805.10(30.08 = inches from fulcrum.
180
510
480

To find the weight of ball.

Rule.—Multiply the area of valve in square inches by the blow-off pressure, and subtract the weight of valve and stem from the product (call this value "A").

Multiply the weight of lever in pounds by the distance in inches from fulcrum to centre of gravity, and divide this product by the distance in inches from fulcrum to centre of valve stem (call this value "B").

Subtract "B" from "A," and multiply the remainder by the distance in inches from the fulcrum to centre of valve stem. Divide this product by distance from fulcrum to centre of weight.

In the preceding example what must the ball weigh to blow off at 75 pounds?

area of valve = 7.07 = square inches.
75 = pressure.
3535
4949
530.25 = pressure on valve.
8.00 = weight of valve and stem.
522.25 = actual pressure on valve.

30 = weight of lever.
16 = distance from fulcrum to centre of gravity.
180
30

distance from fulcrum to valve stem = 6)480(80 = lbs. due to weight of lever.
48

522.25 = actual pressure.
80.00 = due to lever weight.
442.25
6 = distance from fulcrum to [valve stem.

distance from fulcrum to weight = 34)2653.50(78.04 = lbs. weight of ball.
238
273
272
150
136

TUBES.

What proportion is used for the relation of collective tube area to grate area?

It is usually made one-eighth the area of grate.

How are the tubes measured?

By the outside diameter.

How are pipes measured?

By the inside diameter.

What size tubes are usually placed in boilers up to 48 inches diameter?

Common practice is to use tubes $2\frac{1}{2}$ inches diameter.

What size tubes are used between 48 inches and 60 inches diameter?

Usually 3 inches diameter, and above 60 inches use $3\frac{1}{2}$-inch tubes.

What is the average thickness of tubes?

Usually from 0.10 inch to 0.17 inch thick.

What thickness is commonly used for stay-tubes?

Stay-tubes are usually $\frac{1}{4}$ inch thick.

Example.—What is the heating surface per foot for a 3-inch tube $\frac{1}{8}$ inch thick?

$$\begin{array}{rl}
3 & \text{inches} = \text{diameter of tube.} \\
\underline{\frac{1}{4}} & \text{inch} = 2 \times \frac{1}{8}, \text{ or twice thickness.} \\
2\frac{3}{4} & \text{inches} = \text{inside diameter} = 2.75 \text{ inches.}
\end{array}$$

$$\begin{array}{rl}
3.1416 & = \text{constant.} \\
\underline{2.75} & = \text{inside diameter.} \\
157080 & \\
219912 & \\
\underline{62832} & \\
8.639400 & = \text{inside circumference.} \\
\underline{12} & = \text{inches per foot.} \\
172788 & \\
\underline{86394} & \\
103.6728 & = \text{number of square inches.}
\end{array}$$

square inches
per square foot = 144)103.6728(.7199 square feet area per foot length, say .72

```
    1008
    ----
     287
     144
    ----
     1432
     1296
    -----
      1368
      1296
     -----
```

How do you find the total tube-heating surface of boiler?

Rule.—Multiply heating surface per foot of length by the length of tubes in feet, and that product by the number of tubes in boiler.

Example.—A boiler having 110 3-inch tubes, $\frac{1}{8}$ inch thick, is 12 feet between front and back heads. What is the tube-heating surface?

From preceding example, heating surface per foot length =

```
    .72 = square feet.
     12 = length of tubes in feet.
  -----
    144
    72
  -----
   8.64 = square feet per tube.
    110 = number of tubes.
  ------
    864
   864
  ------
 950.40 = square feet total heating surface.
```

Example.—In the preceding example what is collective area in square feet of tube openings?

3-inch diameter tube.

$\frac{1}{4}$ = thickness = $\frac{1}{8} \times 2 = \frac{1}{4}$.

$2\frac{3}{4}$ = inside diameter.

$$
\begin{array}{r}
2.75 \\
2.75 \\
\hline
1375 \\
1925 \\
550 \\
\hline
7.5625 \\
.7854 = \text{constant.} \\
\hline
302500 \\
378125 \\
605000 \\
529375 \\
\hline
5.93958750 = \text{area in square inches.}
\end{array}
$$

$\left.\begin{array}{l}\text{square inches} \\ \text{in one foot}\end{array}\right\}$ = 144)5.93958(.0412 = area in square feet.

$$
\begin{array}{r}
576 \\
\hline
179 \\
144 \\
\hline
355 \\
288 \\
\hline
\end{array}
$$

$$
\begin{array}{r}
.0412 = \text{area of tubes, square feet.} \\
110 = \text{number of tubes.} \\
\hline
412 \\
412 \\
\hline
4.5320 = \text{collective area of in square feet.}
\end{array}
$$

Example.—What percentage of the total boiler volume do the tubes represent in the preceding example, if the diameter is 60 inches?

$$
\begin{array}{rl}
60 & \text{inches} = \text{diameter shell.} \\
60 & \\
\hline
3600 & \\
.7854 & = \text{constant.} \\
\hline
14400 & \\
18000 & \\
28800 & \\
25200 & \\
\hline
2827.4400 & = \text{area in square inches.}
\end{array}
$$

$$
\left.\begin{array}{l}\text{square inches} \\ \text{per square foot}\end{array}\right\} = 144)2827.44(19.635 = \text{area square feet.}
$$

$$
\begin{array}{r}
144 \\
\hline
1387 \\
1296 \\
\hline
914 \\
864 \\
\hline
504 \\
432 \\
\hline
720 \\
720 \\
\hline
\end{array}
$$

$$
\begin{array}{rl}
19.64 & = \text{area.} \\
12 & = \text{length in feet.} \\
\hline
3928 & \\
1964 & \\
\hline
235.68 & = \text{cubic feet volume of shell, say 235.7}
\end{array}
$$

3 inches = diameter tube.
3

9

.7854
9

7.0686 = area in square inches.

square inches per square foot = 144)7.0686(.049 = square feet area.
576

1308
1296

.049 = area square feet.
1 = foot.

.049 = cubic feet for 1 foot length of tube.
12 = length of shell or tube.

98
49

588
110 = number of tubes.

588
588

64.680 = cubic feet occupied by tubes, say 64.7

percentage of tubes volume to shell volume = 235.7)64.700(.27 = per cent. shell volume.
4714

17560
16499

BOILER PLATES.

What thickness plate should be used on a 40-inch boiler to carry 125 pounds' pressure, tensile strength of plate 60,000 pounds?

125 = steam pressure.
6 = factor of safety.
750
20 = $\frac{1}{2}$ diameter boiler.
15000

tensile strength of plate = 60,000)15000.0(.25, or $\frac{1}{4}$-inch thickness of plate.
120000
300000
300000

BURSTING PRESSURE.

How do you determine the bursting pressure of a boiler with single-riveted joint?

Rule.—Multiply the tensile strength of plate in pounds per square inch by the thickness of the weakest plate in hundredths of an inch. Multiply this product by the percentage of strength of a single-riveted joint. Divide the quotient by one-half of the diameter of boiler. This will give the bursting pressure. Divide the last product by 5, which is the factor of safety. This will give safe-working pressure to carry.

Example.—What is the bursting pressure of a boiler, single riveted, having $\frac{1}{4}$-inch steel plates, 60,000 pounds'

tensile strength of plates, assuming strength of joint to be 56 per cent., diameter of boiler 40 inches, factor of safety 5?

```
   60,000 = tensile strength of plate.
      .25 = thickness of plate.
   ------
   300000
  120000
  -------
  15000.00
      .56    = per cent. of strength of joint.
  -------
    90000
   75000
  -------
  8400.00
```

$\frac{1}{2}$ diameter boiler = 40 ÷ 2 = 20)8400.00(420 = lbs. bursting pressure.

```
       80
       --
        40
        40
        --
```

factor of safety = 5)420(84 = lbs. safe-working pressure.

```
    40
    --
     20
     20
     --
```

To determine bursting pressure of double-riveted joint.

Rule.—Multiply the tensile strength of plate in pounds per square inch by the thickness of the weakest plate in hundredths of an inch. Multiply this product by the percentage of strength of a double-riveted joint. Divide the quotient by one-half diameter of the boiler. This will give the bursting pressure. Divide the last product by 5, which is the factor of safety. This will give the safe-working pressure.

Example.—What is the bursting pressure of a boiler double riveted, having $\frac{1}{4}$-inch steel plate, tensile strength

of plate 60,000 pounds, assuming strength of joint to be 70 per cent., diameter of boiler 40 inches, and factor of safety 5?

```
  60,000 = tensile strength of plate.
     .25 = thickness of plate.
  ------
  300000
 120000
--------
 15000.00
     .70 = per cent. of strength of joint.
 --------
 10500.00
```

```
½ diameter boiler = 40 ÷ 2 = 20)10500.00(525 = lbs. bursting
                               100              pressure.
                               ---
                                50
                                40
                               ---
                               100
                               100
                               ---
```

```
factor safety = 5)525(105 = lbs. safe-working pressure.
                  5
                  --
                   25
                   25
                   --
```

How do you find bursting pressure of triple-riveted joint?

Rule.—Multiply the tensile strength of plate in pounds per square inch by the thickness of the weakest plate in hundredths of an inch. Multiply this product by .75, which is the percentage of strength of a triple-riveted joint. Divide the quotient by one-half the diameter of boiler. This will give the bursting pressure. Divide the last product by 5,

which is the factor of safety. This will give the safe-working pressure to carry.

Example.—What is the bursting pressure of a boiler triple riveted, having $\frac{3}{8}$-inch steel plate, tensile strength 60,000 pounds, assuming strength of joint to be 75 per cent., diameter of boiler 66 inches, factor of safety 5?

$$\begin{array}{rl}
60{,}000 & = \text{tensile strength of plate.} \\
.375 & = \text{thickness of plate.} \\
\hline
300000 & \\
420000 & \\
180000 & \\
\hline
22500.000 & \\
.75 & = \text{per cent. strength of joint.} \\
\hline
112500 & \\
157500 & \\
\hline
16875.00 &
\end{array}$$

$\frac{1}{2}$ diameter of boiler $= 66 \div 2 = 33)16875.00(511.36 =$ lbs. bursting pressure.

$$\begin{array}{r}
165 \\
\hline
37 \\
33 \\
\hline
45 \\
33 \\
\hline
120 \\
99 \\
\hline
210
\end{array}$$

factor safety = 5)511.36(102.2 = lbs. safe working pressure.

```
5
--
11
10
--
 13
 10
 --
 36
```

To find the bursting pressure of a butt-strap, triple-riveted joint.

Rule.—Multiply the tensile strength of plate in pounds per square inch by the thickness of the weakest plate in hundredths of an inch. Multiply this product by .82, which is the percentage of strength of a butt-strap joint. Divide the quotient by one-half the diameter of boiler. This will give the bursting pressure. Divide the last product by 5, which is the factor of safety. This will give the safe-working pressure to carry.

Example.—What is the bursting pressure of a boiler with butt-strap joints, triple riveted, having $\frac{3}{8}$-inch steel plates, tensile strength 60,000 pounds, assuming strength of joint to be 82 per cent., diameter of boiler 66 inches, factor of safety 5?

```
      60,000 = tensile strength of plate.
        .375 = thickness of plate.
    ----------
      300000
     420000
    180000
    ----------
    22500.000
          .82 = per cent. strength of joint.
 ------------
        45000
      180000
 ------------
     18450.00
```

$\frac{1}{2}$ diameter boiler = 66 ÷ 2 = 33)18450.00(559 = lbs. bursting pressure.

```
33)18450.00(559
   165
   ---
    195
    165
    ---
     300
     297
     ---
```

factor of safety = 5)559(111.8 = lbs. safe-working pressure.

```
5)559(111.8
  5
  -
   5
   5
   -
    9
    5
    --
    40
```

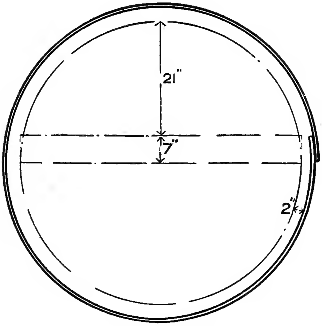


FIGURE 13.

AREA OF BOILER HEAD TO BE BRACED.

How would you ascertain the number of braces which are necessary to strengthen that part of the boiler head which is not stayed by the tubes?

It is first necessary to know its area. The part to be stayed is a segment of a circle. The length of the segment is measured 2 inches above the tubes, and the height or width should be measured from a line, drawn 2 inches above the tubes, to a point within 3 inches from the top of the boiler shell, as shown in the illustration by the dotted line. Some allow a margin of 2 inches.

Rule.—Deduct from diameter of shell 4 inches, and find area of this inner circle. Subtract from one-half this area the number of square inches in the rectangle (shown in the cut). Multiply this remainder by the steam pressure in pounds per square inch. Divide this remainder by the allowable pressure on each stay (which is found by multiplying area of stay by 5,000), the value usually taken in designing. The quotient will be the number of stays necessary to support the segment.

Example.—How many $1\frac{1}{2}$-inch stays should be used on a boiler 60 inches in diameter, carrying 100 pounds' boiler pressure, allowing 5,000 pounds per square inch of area on stay?

2 inches supported all around, to be deducted from diameter.

```
2
--
4

     60
      4
    ----
     56 = inches new diameter.
     56
    ----
    336
   280
   -----
   3136
   .7854 = constant.
 ---------
   12544
  15680
 25088
21952
-------------
2463.0144 = area inside ring.
```

2)2463(1231.5 = ½ area ring.

```
 56 = length rectangle.
  7 = height rectangle.
----
392 = area rectangle.

1231.5
 392.0
------
 839.5 = square inches,
         area segment to be braced.
```

```
839.5   = area.
    100 = steam pressure.
---------
83950.0 = pressure per square inch on segment.
```

```
1½ = 1.5 = diameter stay.
     1.5
    -----
     75
     15
   ------
     2.25
    .7854
   -------
      900
    1125
   1800
  1575
  ---------
  1.767150 = area stay.
```

```
 5000 = allowable pressure.
 1.76 = area of stay in
-------     square inches.
30000
35000
5000
--------
8800.00 = allowable pressure on
          each stay.
```

8800)83950(9.53 = number stays necessary, make 10, $1\frac{1}{2}$-inch stays.
79200
―――
47500
44000
―――
35000
26400
―――

How do you determine strain on longitudinal seam?

Rule.—To determine the strain produced on longitudinal seams tending to tear the seam asunder, multiply the given pressure per square inch in pounds by one-half of the diameter of the boiler in inches, and the product will give the strain, in pounds, on each longitudinal inch along the shell of the entire boiler as well as on the longitudinal seam.

Example.—What is the strain in pounds per inch length on the longitudinal seam of a boiler working under 150 pounds' steam pressure, diameter 48 inches?

150 = steam pressure.
24 = $\frac{1}{2}$ diameter boiler.
―――
600
300
―――
3600 = lbs. strain per inch on seam.

How do you determine the strain per inch on girth seam?

Rule.—Multiply area of boiler head in square inches by the steam pressure, and divide by the circumference of boiler.

Example.—What is the strain per inch on the girth seam on the boiler in above example?

```
area=48
     48
    ---
    384
   192
   ----
   2304
  .7854
  -----
   9216
  11520
 18432
16128
---------
1809.5616
```

```
circumference=3.1416
                  48
              ------
              251328
             125664
            --------
            150.7968, say 150.8
```

```
1809.56  =area boiler head.
     150=steam pressure.
 ---------
 9047800
180956
---------
271434.00
```

```
150.8)271434.0(179.99
      1508
      -----
      12063
      10556
      -----
       15074
       13572
       -----
        15020
        13572
        -----
         14480
         13572
         -----
```

say 180 lbs. strain on girth seam.

The strength of the shell of a cylindrical boiler to resist a pressure within it is inversely proportional to its diameter and directly proportional to the thickness of the plate of which it is formed. For instance, take three cylindrical boilers, each made of ½-inch plate, the first one 2 feet 6 inches in diameter, the second twice that, or 5 feet in diameter, and the third twice that, or 10 feet in diameter; and if the 2-feet-6-inches boiler is safe for a working pressure of 180 pounds to the square inch, then the 5-foot boiler will be safe for exactly one-half that amount, or 90 pounds per square inch, and the 10-foot boiler will be safe for half the working pressure of the 5-foot boiler, which would be 45 pounds.

The working steam pressure allowable on boilers constructed of plates inspected as required when single riveted shall not produce a strain to exceed one-fifth of the tensile strength of the steel plate of which such boilers are constructed.

How would you find the required diameter of a boiler?

To determine the required diameter of a boiler, with single-riveted longitudinal seam, when the working pressure, thickness, and tensile strength are given.

Rule.—Divide the product of the tensile strength of plate times the thickness of the plate by the steam pressure times 6. Multiply this quotient by 2, the product will be the diameter of boiler required.

Example.—What should the diameter of boiler be having $\frac{1}{4}$-inch steel plate, 60,000 pounds' tensile strength, 125 pounds' steam pressure?

$$
\begin{array}{rl}
60{,}000 = & \text{tensile strength of plate.} \\
.25 = & \text{thickness of plate.} \\
\hline
300000 & \\
120000 & \\
\hline
15000.00 & \\
\end{array}
$$

$$
\begin{array}{rl}
125 = & \text{steam pressure.} \\
6 = & \text{constant.} \\
\hline
750 &
\end{array}
$$

$$750)15000(20$$
$$\underline{1500}$$

$$20 \times 2 = 40 = \text{diameter boiler.}$$

How do you determine the thickness of plate for a boiler with single-riveted longitudinal seams, when the diameter, tensile strength of material, and working pressure are given?

Rule.—Multiply the steam pressure in pounds per square inch by 6 and by one-half diameter of boiler. Divide this product by the tensile strength of the plate. The quotient will be the thickness of plate in decimals of an inch.

What thickness of plate should be used on a boiler 40 inches diameter, 125 pounds' working pressure, assuming tensile strength of plate to be 60,000 pounds?

$$\begin{array}{rl} 125 & = \text{working pressure.} \\ 6 & = \text{constant.} \\ \hline 750 & \\ 20 & = \tfrac{1}{2} \text{ diameter boiler.} \\ \hline 15000 & \end{array}$$

$$\left\{\begin{array}{l}\text{tensile strength} \\ \text{of plate}\end{array}\right. = 60{,}000)15000.00(.25 = \tfrac{1}{4}\text{-inch thickness of plate.}$$

$$\begin{array}{r} 120000 \\ \hline 300000 \\ 300000 \\ \hline \end{array}$$

CHAPTER III.

RIVETED JOINTS.

Define a single-riveted lap joint.

In a single-riveted lap joint the surfaces of the plate overlap and the plates are held in position by one row of rivets.

Define a double-riveted lap joint.

In a double-riveted lap joint the surfaces of the plates overlap and the plates are held in position by two rows of rivets.

Define a butt-strap joint.

A joint in which the edges of the plate come together having a true circle, and are held in position by riveting through the inside and outside cover plate.

Define a double-riveted butt joint.

It is a joint in which the edges of the plate come together forming a true circle with inner and outer cover plates and having an inner row of rivets in double shear and outer row in single shear.

Define a triple-riveted butt joint.

A joint in which the edges of the plates come together forming a true circle and having inner and outer cover plates with the inner rows of rivets in double shear and the outer row in single shear.

In what way may a riveted joint fail?

1st, by shearing rivets.

2d, by tearing plates between the rivets.

3d, by crushing the rivet or plate in front of a rivet or by a combination of two or more of the above causes.

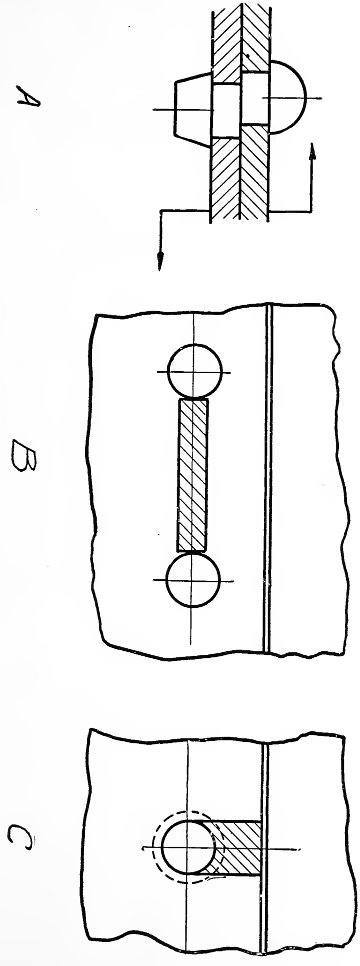


FIGURE 14.

Figure 14 shows in what way a riveted joint may fail.

At A is shown the shearing of a rivet.

At B is shown tearing plate between rivet holes.

At C is shown crushing plate in front of rivet.

How is the resistance to shear one rivet found?

By multiplying area of rivet by its shearing strength.

How is the resistance to tear the plate between the rivets found?

Multiply the distance between rim edges of hole by the thickness of plate and this product by the given tensile strength of the plate.

How is the resistance to crush the rivet or plate found?

Multiply diameter of rivet by the thickness of plate and the product by the crushing strength of the rivet or plate.

How is the strength of solid plate found, and why used?

By multiplying the pitch of rivets by the thickness of plate and this product by the tensile strength given for the plate. It is used for calculating the efficiency of the joint

What is meant by a single shear of a rivet?

Single shear of a rivet is where it passes through two plates and would shear or cut-off in one plane only.

Give an illustration of a rivet in single shear.

Rivets are in single shear in a single-riveted lap joint.

What is meant by double shear?

Double shear of a rivet is where the rivet passes through three plates and it is possible to shear rivet in two planes.

Give illustration of a rivet in double shear.

The rivets in a double-riveted or triple-riveted butt joint.

What is meant by the tensile strength of a plate?

The tensile strength of a plate is the number of pounds the plate will stand in tension or pulling apart for each square inch of its area.

What is meant by the shearing strength of a plate?

The shearing strength of a plate is the number of pounds necessary to cut across the plate.

What is meant by the crushing strength of a plate?

The crushing strength of a plate is the number of pounds necessary to crush or press together the surfaces of the plate.

What is the average tensile, shearing, and crushing strength of steel and wrought-iron plate?

	Steel.	*Iron.*
Tensile	60,000 pounds	45,000 pounds
Shearing	50,000 "	38,000 "
Crushing	90,000 "	74,250 "

What is a test piece?

A piece cut from the sheet from which tests are made to ascertain the various strengths of the plate to be used.

How is the pitch of rivets for single-riveted joints found?

Rule.—Multiply the diameter of rivet hole by 7. Divide this product by eight times the thickness of the plate, and to this quotient add 1, then multiply this sum by diameter of rivet hole.

Example.—What pitch should be used for a single-riveted joint having $\frac{3}{4}$-inch rivet and $\frac{1}{4}$-inch plate?

$$\begin{array}{r l}
\text{Diameter of rivet hole, } \frac{3}{4} = .75 & \\
7 & = \text{constant.} \\
\hline
5.25 &
\end{array}$$

$$\begin{array}{r}
\text{thickness of plate, } \frac{1}{4} = .25 \\
\text{constant} = 8 \\
\hline
2.00)5.25(2.62 \\
400 \\
\hline
1250 \\
1200 \\
\hline
500 \\
400 \\
\hline
\end{array}$$

$$\begin{array}{r l}
2.62 & \\
1.00 & \text{to be added.} \\
\hline
3.62 & \\
.75 & = \text{diameter of rivet hole.} \\
\hline
1810 & \\
2534 & \\
\hline
2.7150 & = \text{pitch, say } 2\frac{3}{4} \text{ inches.}
\end{array}$$

How is the pitch of rivets for a double-riveted lap joint found?

Rule.—Multiply diameter of rivet hole by 7. Divide this product by four times the thickness of plate, to this quotient add 1, then multiply this sum by diameter of rivet hole.

Example.—What pitch should be used for a double-riveted lap joint having $\frac{3}{4}$-inch rivets and $\frac{3}{8}$-inch plate?

rivet diameter, $\frac{3}{4}=.75$

$$\begin{array}{r} .75 \\ 7 = \text{constant.} \\ \hline 5.25 \end{array}$$

$$\begin{array}{r} \tfrac{3}{8}\text{-inch plate} = .375 \\ \text{constant} = \quad 4 \\ \hline 1.500 \end{array}$$

$$\begin{array}{r} 1.50)5.25(3.5 \\ 450 \\ \hline 750 \\ 750 \\ \hline \end{array}$$

$$\begin{array}{r} 3.5 \\ 1.0 = \text{to be added.} \\ \hline 4.5 \\ .75 = \text{diameter rivet hole.} \\ \hline 225 \\ 315 \\ \hline 3.375 = \text{pitch of rivets } 3\tfrac{3}{8} \text{ inches.} \end{array}$$

How is the pitch of rivets for a double-riveted butt joint found?

Rule.—Multiply diameter of rivet hole by 7. Divide this product by two times the thickness of plate, to this quotient add 1, then multiply this sum by the diameter of rivet hole.

Example.—What pitch should be used for a double-riveted butt joint having $\frac{11}{16}$-inch rivets and $\frac{9}{16}$-inch plate?

diameter of rivet hole, $\frac{11}{16} = .6875$

$$\begin{array}{r} .6875 \\ 7 = \text{constant.} \\ \hline 4.8125 \end{array}$$

thickness of plate, $\frac{9}{16} = .5625$

$$\begin{array}{r} .5625 \\ 2 = \text{constant.} \\ \hline 1.1250 \end{array}$$

$$\begin{array}{r} 1.125)4.8125(4.27 \\ 4500 \\ \hline 3125 \\ 2250 \\ \hline 8750 \\ 7875 \\ \hline 875 \end{array}$$

$$\begin{array}{l} 4.27 \\ 1 \quad \text{to be added.} \\ \hline 5.27 \end{array}$$

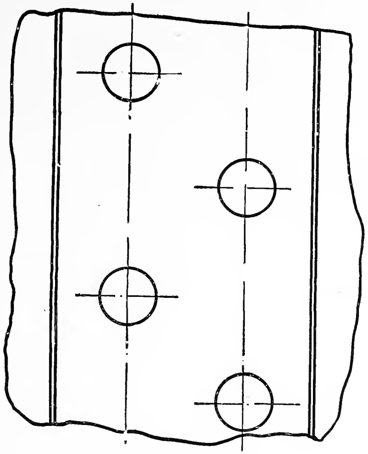
$$\begin{array}{r} .6875 = \text{diameter of rivet hole.} \\ 5.27 = \text{sum.} \\ \hline 48125 \\ 13750 \\ 34375 \\ \hline 3.623125 = \text{pitch of rivet } 3\tfrac{5}{8} \text{ inches.} \end{array}$$

How is the diameter of a rivet hole found for a single-riveted and double-riveted lap joint?

Diameter equals thickness of plate plus $\frac{3}{8}$ of an inch.

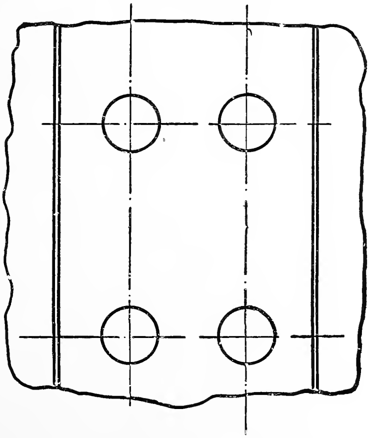
How is the diameter of a rivet hole found for butt joints with cover plates?

Diameter equals one and one-quarter times the thickness of plate.



STAGGERED

Figure 15.



CHAIN

Figure 16.

How much smaller is the diameter of a rivet than the rivet hole?

Usually the rivet is $\frac{1}{16}$-inch smaller in diameter than the hole, to allow rivet to upset and completely fill hole when driven and headed.

What is staggered riveting?

Joints having two rows of rivets, the rivets in the second row being placed midway between rivets of first row.

What is chain riveting?

Joints having two rows of rivets, with the second row in line with or above rivets in first row.

What is meant by the efficiency of a joint?

The relation of strength of the joint to the strength of the solid plate.

How is the efficiency of a joint found?

Rule.—1st, multiply pitch of rivets by strength of plate, and this product by thickness of plate.

2d, subtract diameter rivet hole from the pitch of rivets, multiply this remainder by the thickness of the plate and the tensile strength of plate.

3d, multiply area of one rivet by the number of rivets, and multiply this product by the shearing strength of rivet.

4th, divide the weaker of these by the strength of solid plate, the quotient will be the percentage of strength of the joint?

What values may safely be taken for the efficiency of riveted joints?

Single-riveted	joints,	56%.
Double- "	"	·70 "
Triple- "	"	75 "
Butt-strap "	"	85 "

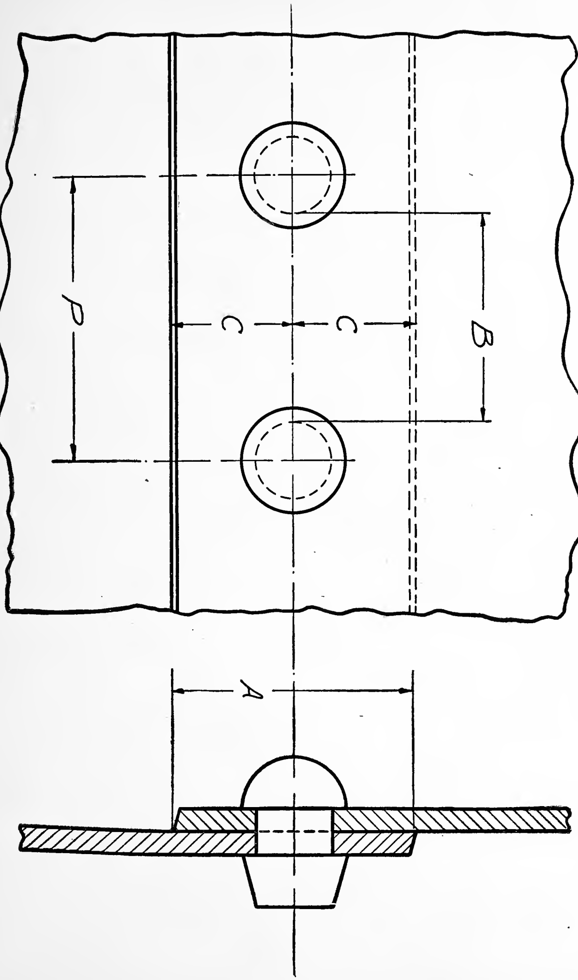


FIGURE 17.

SINGLE-RIVETED LAP JOINT.

P represents pitch of rivet. (See rule.)

A represents lap of plate, and usually made to equal three times the diameter of rivet.

B represents distance between holes.

C, lap from centre of rivet and usually equal to one and one-half times the diameter of rivet.

Find the efficiency of a single-riveted lap joint by rules previously given.

Example.—Using $\frac{3}{4}$-inch iron rivet, $\frac{1}{4}$-inch steel plate, and $1\frac{3}{4}$-inch pitch, assume tensile strength of plate to be 60,000 pounds, shearing strength of rivet 38,000 pounds.

$$\begin{array}{r l}
60{,}000 & \\
.25 & = \tfrac{1}{4}\text{ inch} = .25 \\
\hline
300000 & \\
120000 & \\
\hline
15000.00 & \\
1.75 & = \text{pitch} = 1\tfrac{3}{4}\text{ inches.} \\
\hline
7500000 & \\
10500000 & \\
1500000 & \\
\hline
26250.0000 & = \text{lbs. to break solid plate.}
\end{array}$$

$$\begin{array}{r l}
15000 & \\
1 & = \text{distance between holes.} \\
\hline
15000 & = \text{lbs. to break plate between holes.}
\end{array}$$

area $\frac{3}{4}$-inch rivet = .44 square inches. (See table.)

```
  38,000
     .44
 --------
 152000
152000
 --------
16720.00=lbs. to shear rivet.
```

```
26,250)15000.00(.5714=57.14 per cent. strength of
       131250                       joint.
       ------
        187500
        183750
        ------
          37500
          26250
         ------
          112500
          105000
         ------
```

DOUBLE-RIVETED LAP JOINT.

P represents pitch of rivets. (See rule.)

A represents lap of plate, and usually made to equal four and one-half times the diameter of rivet.

B represents distance between holes.

C, distance between rows of rivets, and usually equal to one and one-half times diameter of rivets.

Example.—What is the efficiency of a double-riveted lap joint using $\frac{3}{4}$-inch iron rivet, $\frac{1}{4}$-inch steel plate, 3-inch pitch, assuming tensile strength of plate 60,000 pounds, shearing strength of rivet 38,000 pounds?

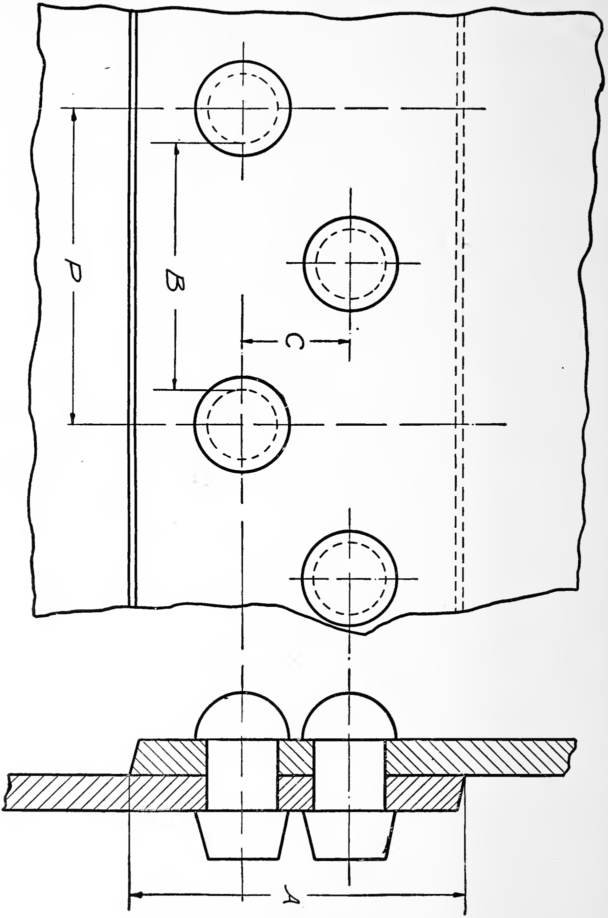


FIGURE 18.

60,000

.25 = $\frac{1}{4}$-inch thickness of plate.

300000

120000

15000.00

3 = pitch of rivet.

45000 = lbs. to break solid plate.

15000

2.25 = distance between holes.

75000

30000

30000

33750.00 = lbs. to break plate.

area $\frac{3}{4}$-inch rivet = .44 square inches.

38,000

.44

152000

152000

16720.00 = lbs. to shear 1 rivet.

2

33440 = lbs. to shear 2 rivets.

45,000)33440.0(74.31 = per cent. strength of joint.

315000

194000

180000

140000

135000

50000

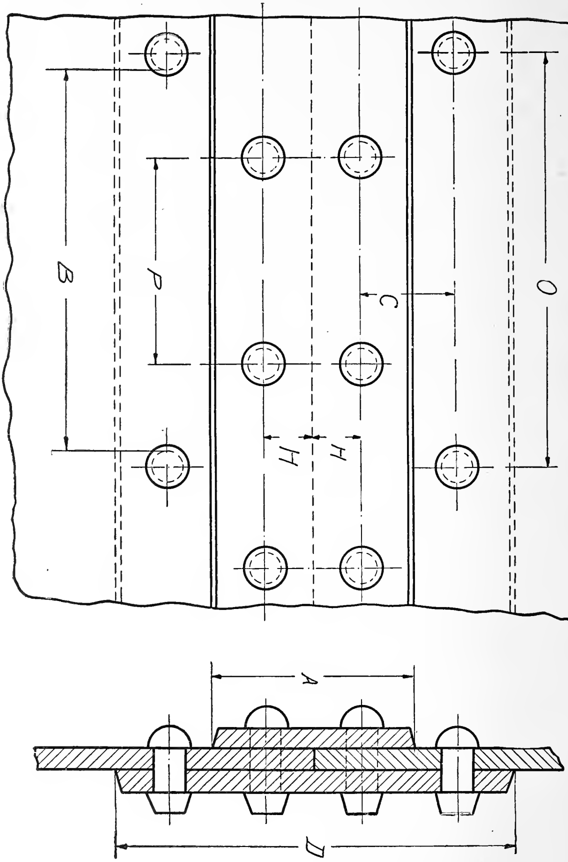


FIGURE 19.

DOUBLE-RIVETED BUTT JOINT.

P represents pitch of inner row. (See rule.)
A represents width of outside cover plate.
B represents distance between holes on outer row.
C represents distance from first row to outer row.
D represents width of inner cover plate.
H represents distance from butt to first row of rivets.
O represents pitch of outer row of rivets.

Example.—What is the efficiency of a double-riveted butt joint having $\frac{3}{8}$-inch steel plate, $\frac{3}{4}$-inch iron rivet, $2\frac{1}{2}$-inch pitch inner row, 5-inch pitch outer row, assuming tensile strength of plate to be 60,000 pounds, shearing strength of rivets 38,000 pounds?

1st, resistance to tear at outer row.

5 inches — $\frac{3}{4}=4\frac{1}{4}$ inches $=4.25=$ decimal.

$$\begin{array}{rr}
 & .375 = \text{thickness of plate.} \\
\text{distance between rivets} = & 4.25 \\
\hline
 & 1875 \\
 & 750 \\
 & 1500 \\
\hline
 & 1.59375
\end{array}$$

$$\begin{array}{r}
1.59 \\
60{,}000 \\
\hline
95400 = \text{lbs. to tear at outer plate.}
\end{array}$$

2d, resistance to shear.

2 rivets in double shear and 1 rivet in single equals 5 rivets in single shear.

```
 38,000 = shearing strength of rivet.
      5
 ------
 190000
    .44 = area of rivet.
 ------
 760000
760000
---------
83600.00 = lbs. to shear 5 rivets.
```

3d, resistance to crush in front of 3 rivets.

```
 .375 = thickness of plate.
    3 = number of rivets.
 -----
 1.125
   .75 = diameter of rivet.
 -----
  5625
 7875
------
.84375
```

```
 90,000 = crushing strength of plate.
    .84
 ------
 360000
720000
--------
75600.00 = lbs. to crush in front of 3 rivets.
```

4th, resistance to crush in front of 2 rivets and shear 1 rivet.

```
 .375 = thickness of plate.
    2 = number of rivets.
 ----
 .750
  .75 = diameter of rivet.
 ----
  3750
 5250
------
.56250
```

```
   38,000=shearing strength of rivet.
      .44=area of rivet.
  -------
   152000
  152000
 --------
 16720.00

   90,000=lbs. crushing strength of plate.
      .56
  -------
   540000
  450000
 --------
 50400.00
 16720
 --------
 67120.00=lbs. to crush in front of 2 rivets and
                 shear 1 rivet.
```

Values from calculations then equal:—

95,400 pounds to tear at outer row.
83,600 pounds to shear 5 rivets.
75,600 pounds to crush in front of 3 rivets.
67,120 pounds to crush in front of 2 rivets and shear 1 rivet.

Select lowest value, 67,120 pounds.
Shearing strength of solid plate=

```
       .375=thickness of plate.
          5=outside pitch.
      -----
      1.875

     60,000=tensile strength of plate.
      1.875
     ------
     300000
    420000
   480000
   60000
 ----------
 112500.000=lbs. strength of solid plate.
```

```
112,500)67120.0(.5967=59.67 per cent. strength of
        562500              joint.
       -------
        1087000
        1012500
       --------
          755000
          675000
         -------
           800000
           787500
```

TRIPLE-RIVETED BUTT JOINT.

P represents pitch of rivets, inner rows.
A, width of outside cover plate.
B, distance between holes, outer row.
C, width of inside cover plate.
D, pitch of outer row of rivets.

Example.—What is the efficiency of a triple-riveted butt joint having $\frac{7}{16}$-inch steel plate, $\frac{7}{8}$-inch iron rivets, pitch of inner rows $2\frac{5}{8}$ inches, pitch of outer row $5\frac{1}{8}$ inches, assuming tensile strength of plate to be 60,000 pounds and shearing strength of rivets to be 38,000 pounds, thickness of cover plates $\frac{7}{16}$ inches?

1st, resistance to tear at outer row.
$5\frac{1}{8}$ inches $-\frac{7}{8}$ inch $=4\frac{1}{4}$ inches = distance between holes.

```
plate, 7/16 = .4375 = decimal.
            60,000 = strength of plate.
        ----------
        26250.0000
            4.25 = distance between holes.
       -----------
       131250
       52500
     105000
     ---------
     111562.50 = lbs. to break plate between holes.
```

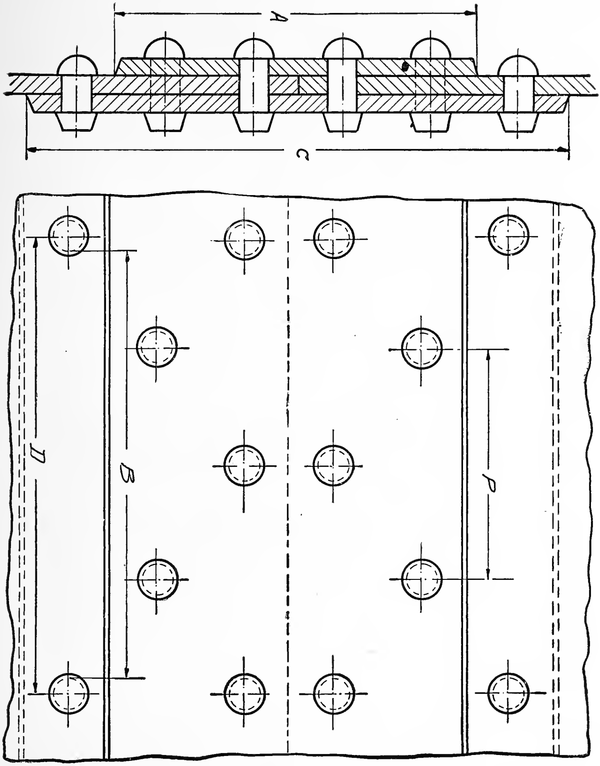


FIGURE 20.

2d, resistance to shear rivets.

4 rivets in double, 1 in single shear, equal 9 rivets in single shear.

$$
\begin{array}{rl}
38,000 & \\
.6 & = \text{area of rivet.} \\
\hline
22800.0 & \\
9 & \\
\hline
205200 & = \text{lbs. to shear 9 rivets.}
\end{array}
$$

3d, resistance to crush in front of 5 rivets.

Five times diameter of rivet times thickness of plate, by this product times the crushing strength of plate, plus diameter of rivet times thickness of inner cover plate, times crushing strength of plate.

$\frac{7}{8}$ diameter of rivet, .875 = decimal.

$$
\begin{array}{rl}
5 & = \text{number of rivets.} \\
\hline
4.375 & \\
.4375 & = \text{thickness of plate.} \\
\hline
21875 & \\
30625 & \\
13125 & \\
17500 & \\
\hline
1.9140625 &
\end{array}
$$

$$
\begin{array}{rl}
.875 & = \text{diameter of rivet.} \\
.4375 & = \text{thickness of cover plate.} \\
\hline
4375 & \\
6125 & \\
2625 & \\
3500 & \\
\hline
.3828125 &
\end{array}
$$

```
      .38
        90,000=crushing strength of steel.
    ________
    34200.00


  1.914
        90,000=crushing strength of steel.
 ____________
  172260.000
    34200
__________
  206460=crushing strength of plate in lbs. in
                front of 5 rivets.
```

4th, resistance to crush in front of 4 rivets and shear 1 rivet.

Four times diameter of rivet multiplied by thickness of plate, times crushing strength of plate, plus area of rivet multiplied by the shearing strength.

```
 7/8 diameter of rivet, .875=decimal.
                           4
                       _____
                       3.500
                       .4375=thickness of plate.
                     _______
                       17500
                      24500
                     10500
                    14000
                   _________
                   1.5312500
```

$$
\begin{array}{rl}
38{,}000 & = \text{shearing strength of rivet.} \\
.6 & = \text{area of one rivet.} \\
\hline
22800.0 &
\end{array}
$$

$$
\begin{array}{rl}
1.53 & \\
90{,}000 & = \text{crushing strength of plate.} \\
\hline
137700.00 & \\
22800 & \\
\hline
160500 & = \text{lbs. to crush in front of 4 rivets and shear 1 rivet.}
\end{array}
$$

Values for calculations then equal:—

111,562.5 pounds to break plate between holes.
205,200 pounds to shear 9 rivets.
206,460 pounds to crush in front of 5 rivets.
160,000 pounds to crush in front of 4 rivets and shear 1 rivet.

Select smaller value or weakest part of joint=111,562.5 pounds.

Strength of solid plate=

$$
\begin{array}{lr}
\text{outer pitch of rivets, } 5\frac{1}{8} & =5.125 \\
\text{thickness of plate, } \frac{7}{16} & =.4375 \\
\hline
 & 25625 \\
 & 35875 \\
 & 15375 \\
 & 20500 \\
\hline
 & 2.2421875
\end{array}
$$

tensile strength of plate = 60,000

```
        60,000
          2.24
      --------
        240000
       120000
      120000
      ---------
      134400.00

134,400)111562.5(.8307 = 83.07 per cent. strength of
        1075200              joint.
        -------
         404250
         403200
         -------
          1050000
           940800
          -------
```

CHAPTER IV.

HEATERS.

What is a heater?

A heater is a tank where the exhaust steam from the engine passes through to heat the water on the way to the boiler.

Describe them.

There is an open heater and a closed heater. A closed heater is one in which the steam passes through between the shell and a brass coil which the water passes through to be heated, then to the boiler.

An open heater is one in which the water and steam mingle. The pump is between the heater and the boiler and below the heater, as the pump will not lift hot water.

A closed heater is between the pump and the boiler.

How may you know if a closed heater leaks?

Where the exhaust goes out of doors, you may notice an excessive amount of water with steam, also from the drip you will notice much water escapes. If heater leaks, the pump will run faster. A by-pass on heater is to pass water around the heater to boiler when heater leaks.

The water supply to open heater is controlled by a float in the heater, shutting a valve from the supply when the water rises to a certain point in the heater. Heater should heat the water to 210° from a non-condensing engine.

There are plants that have receivers where returns from buildings are pumped through heater to boiler.

How hot can a heater heat the water?

In a closed heater to about 130°, in an open heater 210°.

The most economical way to heat water is by waste heat,

the exhaust steam from the engine. By this, in a first-class heater, the feed water can be heated to 210°. Difference or saving between using feed water at 60° and, say, 200° is about 13 per cent. of the coal consumed in making steam.

As a given weight of coal is used in both cases, about fifteen per cent. more effect will be obtained from the feed water at 200° over that of cold water.

For every 10° added to the temperature of feed water by exhaust steam, nearly one per cent. of fuel is saved.

What does it heat with?

It heats the water with the exhaust steam from the engine. This exhaust steam goes into a heater through which the water is passed in a coil of pipe, and then after leaving the heater goes through pipes to heat the building in the winter. In the summer the back-pressure valve is opened to allow the steam to go outdoors.

What are the different kinds of heaters?

There are the open heaters and the closed heaters.

What is an open heater?

An open heater is one in which the steam and the water mingle. This heater is placed above the pump, so that the water may flow to the pump. On account of being hot the pump cannot lift it. The open heater heats water the hotter.

What is a closed heater?

A closed heater is one in which the steam and water do not mingle. The heater is placed between the pump and the boiler. If the heater leaks, there is a by-pass around the heater. In the exhaust pipe there is a back-pressure valve. This is weighted according to the back pressure desired for heating, usually about six pounds.

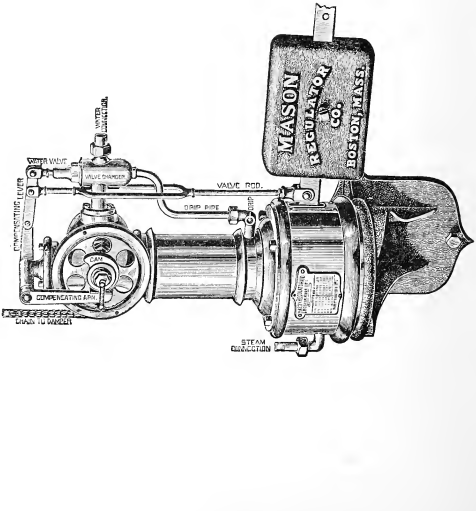


FIGURE 21.

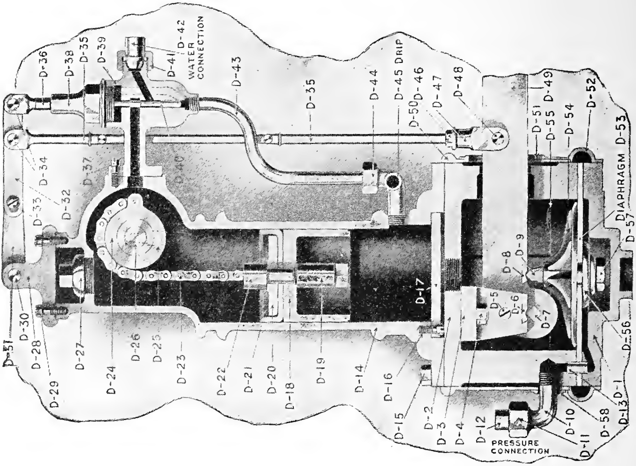


FIGURE 22.

DAMPER REGULATOR.

The damper regulator is controlled by steam pressure from the boiler acting upon the rubber diaphragm and on the water beneath it. When the pressure increases in the boiler, the diaphragm rising lifts the weighted lever, which, as it lifts, opens a small water valve to admit water under city pressure beneath a piston in a small cylinder. This piston is then moved by the water pressure, and sets the damper through suitable chains. When pressure drops on boilers, the diaphragm, lever, and valve are reversed, and water admitted to the other side of the piston, or water allowed to escape from the cylinders, which are single acting. The SPENCER is double acting. The damper closes a little at a time. If it sticks, the trouble is usually with a sticky valve, this valve being easily removed, and a new one substituted. The water before entering regulator passes through a reservoir in which soft soap is placed to lubricate valve.

HEATING SYSTEM.

Describe a heating system.

There are two systems of heating, direct and indirect. Direct heating is where the radiators are in the room to be heated. In indirect heating the radiators are in a room in the basement where air is heated. The radiators are in a room, almost always hung up to timbers, and are boxed in with galvanized iron, and a check or damper connects with the outside air, which is controlled by hand. And sometimes the radiators are in a room in the basement where air is heated and then taken through flues to the rooms to be heated.

What is a gravity system?

In the gravity system of heating the steam is taken from the boiler in pipes to the radiators, and, after being condensed into the water in the radiators, it flows back in another pipe to the basement into a pipe called the "return pipe," which enters the boiler below the water line. This is the double-pipe system.

What is a single-pipe system?

In a single-pipe system the water condensed is returned from the radiators through the same pipe from which steam is taken. Single-pipe systems require the larger piping. The water is returned to the boiler, in the gravity system, by the water seeking its own level. The pressure in the return pipe being nearly the same as in the boiler, the water in the return pipe will level itself up in the return pipe and boiler. The height of the water in the return pipe in the cellar will be slightly higher than in the boiler, according to the loss in pressure in the steam passing through the radiators. On the main pipe a shut-off valve is placed. On the return pipe there is a check-valve, and between it and the boiler a shut-off valve. Were there no check-valve on return pipe and the main valve were to be closed, the pressure in the boiler would fill the system with water. In a heating system, if you have to shut off steam from the building, be sure and shut the return valve first, to prevent the water backing from the boiler into the return pipe; that is, if there is no check-valve on the return pipe. Where a high-pressure boiler is used in a heating system, the water will not then flow back to the boiler by gravity, but is returned by a pump or return traps. If radiators are below the water line of the boiler, two traps are used, a common trap and a return trap, to return the water to the boiler. A return trap is placed 3 feet above the boiler. Return traps are used when radiators are below

the boiler. They work by allowing the full boiler pressure to come on top of the water in the trap, and, when the pressure is equal, water will flow in the boiler.

What is a Bundy return trap?

In a Bundy return trap, when the trap is full, the bowl tips, opening the live-steam connection to the boiler, and full-boiler pressure enters through a pipe, the pressure between trap and boiler is equalized, and water flows into boiler itself, through a pipe and check-valve. When the trap is emptied, the bowl is tipped back by a counter-weight, the live-steam connection shut off, and a vent opened to allow the steam in the trap to escape. There is then no pressure in the trap, and it will again receive water from the heating system. Water enters through a check and passes out through a check valve, passing into the trap through a trunnion. In a Pratt and Cady trap a float rises with the water and opens the live-steam valve, and, when emptied, closes the live-steam valve and opens the vent. Where radiators are below the water line, a common trap is used to keep radiators clear, and this common trap delivers its water into a return trap. There would be needed in the radiators 1 pound pressure to every 2 feet the water must be lifted from the common trap into the return trap. Where radiators are above the water line, but under pressure much lower than the boiler, return may flow direct into the return trap, but usually comes to a receiver, with a check on each pipe into receivers, to prevent water backing up the different pipes if pressure is less in one pipe than in the other.

What is a vacuum system?

When heating by exhaust steam in a large building, an air pump is placed on returns, to keep them clear and to keep back pressure off engine. This makes a rapid circulation, and

pumps the water into a receiver from which it is pumped into the boiler. Sometimes a small condenser or a jet of water is needed at the air pump to cool the returns.

In heating with exhaust steam, there is needed on exhaust pipe a back-pressure valve and a stop-valve. If exhaust steam is not enough, add live steam through a reducing valve. Add weight to the back-pressure valve to get more back pressure, the usual amount being 5 to 7 pounds.

The piping for exhaust steam is larger than for high pressure, returns being trapped back to a receiver and pumped into boiler or wasted.

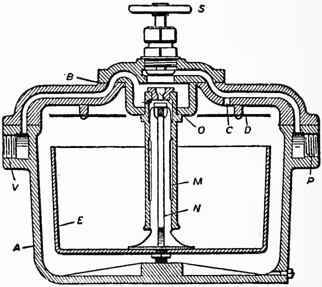


FIGURE 23.

TRAPS.

The steam trap is used to drain the water out of radiators and not let the steam escape. The common kinds are the bucket trap, float trap, and expansion trap. In a bucket trap a bucket floats on the water in a trap, and, when the trap is filled, the water overflows into the bucket, sinking it and opening the valve, and the steam pressure forces the

water out of the trap. When water is gone, bucket floats again, shuts the valve, and no steam can escape.

What is the valve on the top of bucket for?

There is a valve on top of the bucket traps which opens a by-pass which allows the water to be blown out of heating system without going through the trap valve. This is to clear the system of water quickly in the morning. When the steam comes, this valve is shut, and takes care of the water. All traps have some such device. These common traps will deliver the water against any pressure less than pressure in the radiators. When water from the trap is to be elevated, there must be a pressure in the radiators sufficient to do this, and this pressure will be 1 pound for every 2 feet of water to be raised. Heating returns sometimes return to a tank and are pumped into the boiler.

Where is the pump situated?

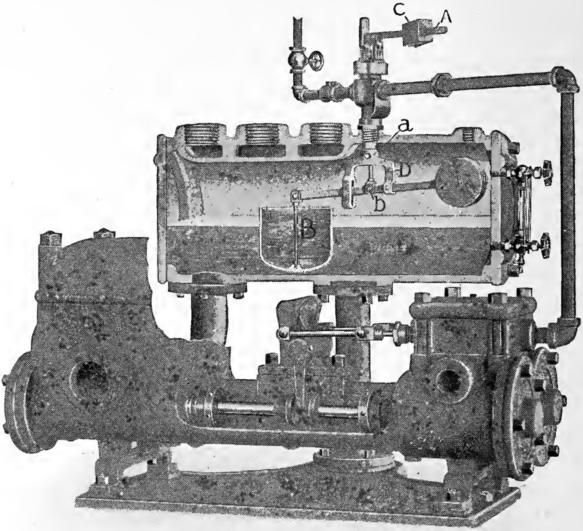
The pump is below the tank, and is controlled by float inside the tank. When water gets high in the tank, this float rises and opens the steam valve to the pump, and pumps water from the tank into the boiler. If float leaks, fills with water, collapses, or drops off the stem, it will not work. To prevent collapsing, ribs are put on the float to stiffen it.

What if returns are hot?

When returns are too hot for the pump, pump will run very fast and uneven, in which case open cold-water pipe to tank, and open drips on pump to let the steam out of water end. All traps have their valves at the lowest point of the water, and in a "Bundy" trap a pipe inside drips down into the water to keep the end water sealed, so steam cannot escape. The drips on water end are to drain water from cylinder to prevent freezing when pump is idle. They are shut when pump is running.

What is the pet cock on air chamber for?

The pet cock on air chamber is to open to see if pump is pumping properly. If water is too hot for pump, pump will



GURE 24.

race badly. In this case open drips and cool water by opening city supply to tank.

What is a float and expansion trap?

The float trap has a float which rises with the water and opens the valve to let the water escape, and, when the water is out of the trap, float falls and shuts the valve. In expan-

sion trap the water in the brass pipe causes it to contract and open the valve, and, when the water is gone and the steam comes, this pipe will expand and shut the valve.

VENTILATION.

How are school buildings heated?

School buildings are heated by direct and indirect heating. Ventilation is obtained by forcing fresh air into the rooms after it has passed over indirect radiators in air room in the basement. The foul air is drawn out of the rooms by large heated chimneys or by fans.

How is the temperature controlled?

The temperature is controlled in indirect heating by pulling a chain in the inlet register in the room, this opening a mixing damper to allow cold air to mix with the warm air and partially shut off the warm air at the same time. If mixing damper is shut entirely, nothing but cold air will enter the room. At night the building is warmed by shutting the dampers in outlet to foul-air chimney or ventilating stack, opening doors from rooms to corridors and cellar, and opening door from cellar to cold-air room. Shutting outside windows in the cold-air room, the same air is then circulated around the building and over the radiators to keep the building warm. In school hours, door to cold-air room is closed, and the outside windows opened and fresh air taken from the outside.

Cold-air windows must be opened wider in very cold weather, not shut up, in order to supply more air necessary to carry up more heat. The circulation is maintained in the ventilating stack by fans, or in the gravity system by a small radiator at the base of the ventilating stack.

REDUCING VALVES.

What is a reducing valve?

A reducing valve is used to heat a building at low pressure from a high-pressure boiler.

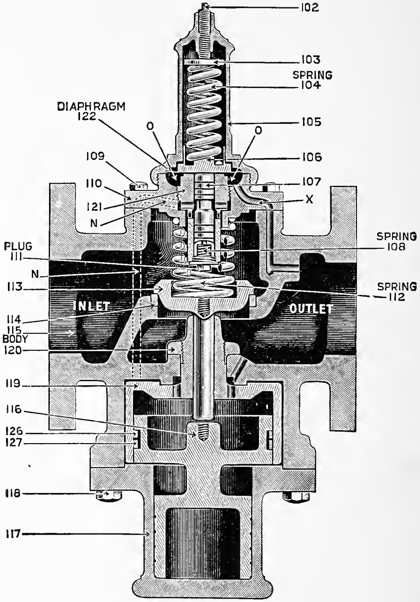


FIGURE 25.

What valves should there be on this?

There should be a shut-off valve between it and the boiler, a steam gauge beyond the reducing valve, and a relief valve to prevent over-pressure if reducing valve fails. To increase

the pressure, screw down on spring or with lever reducing valve, add additional weights.

There are two kinds of reducing valves. One is controlled by a weighted lever, and the other with a spring. They are to reduce a high pressure to a low in heating building.

CHAPTER V.

ENGINES.

What is a high-speed engine?

An engine whose piston runs at a velocity of 600 feet or more per minute at regular work. These engines are provided with an automatic cut-off by means of shifting the eccentric across the shaft so as to reduce the eccentric throw and valve travel. This causes the valve to cut off the steam earlier.

The eccentric, instead of being fixed upon the crank shaft, has an elongated slot, and is hung on an arm that is pivoted to its other end after the manner of a pendulum.

How do you find the clearance?

The head clearance is the distance between the piston at the end of the stroke and the cylinder head. The actual clearance is the whole space from the piston at the end of the stroke, including the ports to the face of the valve. To find the head clearance, put the piston at the end of the stroke and see how far across head is from the striking point. The striking points are marked on the glide at each end of the stroke. This shows where the cross-head would be if the piston touched the head. Take twice the length of the crank and set it equally between the striking point, and the space on either end should be the head clearance.

What is the position of an engine when on dead centre?

The engine is said to be on the centre when the piston rod, cross-head, and connecting rod and crank are all in a straight line.

If steam were admitted at this time, it would have no effect on engine. It can have no effect to drive the engine until the piston is off the centre. It would be necessary to move the crank up or down, to produce such rotary motion; and this is accomplished in actual operation by the momentum of the fly-wheel secured to the shaft. The movement of the piston from one end of the cylinder to the other end is the stroke, and one complete circle of the fly-wheel is a revolution, making two strokes.

Absolute Back Pressure.

Usually taken at about 3 pounds for condensing engine and 17 pounds for non-condensing engine.

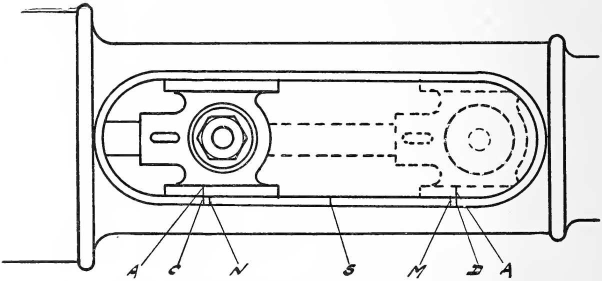
Piston speed used in modern practice is about as follows:—

Small stationary	engine,	300 to	600	feet	per	minute.
Large	"	"	600 "	1,000	"	"	"
Corliss	"	"	400 "	750	"	"	"
Locomotive,			600 "	1,200	"	"	"

How do you find the dead centre of an engine?

Roll the engine in the direction in which it is to run until the approximate extreme travel is reached, then make a mark "D" on the guide at the end of the shoe. Now roll the engine over to opposite extreme throw, and make a mark "C" on the guide at the end of the shoe. Then measure in one-half of an inch from each mark, "M" and "N," and make another mark. Now roll the engine over till the end of the shoe is in line with one of your second inside marks, then make a mark on fly-wheel rim corresponding with a stationary mark on the floor. Now roll the engine over the centre till the end of the shoe comes back to this same inside or second mark, then make a mark on fly-wheel rim cor-

responding with your stationary mark on the floor. Now roll the engine over to opposite end till the shoe coincides with the second or inside mark on that end, mark on fly-wheel rim corresponding with this stationary mark on the floor. Now roll the engine over the centre till shoe comes back to this second or inside mark, then make another mark on the fly-wheel rim the same as before. Now measure off one-half of this distance on the fly-wheel rim, or, in other words, find the centre between the two marks you have just



METHOD OF LOCATING STRIKING POINTS

FIGURE 26.

made on fly-wheel rim. Roll the engine till this centre mark corresponds with this stationary mark on the floor, then engine will be on dead centre on that end. Now measure one-half of the distance between your other two marks on fly-wheel rim, roll the engine till this mark corresponds with your stationary mark. This will give you the dead centre on that end.

Clearance.

What is clearance?

When the crank is on dead centre and the piston at the end of its stroke, there is always a space between the piston and the cylinder head. The volume of the space plus the volume of the steam port leading into it is called the clearance. The piston is at the end of its return stroke, and the clearance is the volume of the space between the piston and the cylinder head, plus the volume of the steam port. In other words, the clearance may be defined as the volume of steam between the valve and the piston, when the latter is at the end of its stroke. The clearance of an engine may be found by putting the engine on dead centre and pouring in water until the space between the piston and the cylinder head and steam port leading into it is filled. The volume of the water poured in is the clearance.

The clearance may be expressed in cubic feet, cubic inches, or percentage.

If the compression were carried up to the boiler pressure, there would be very little, if any, loss, since it would then fill the entire clearance space at boiler pressure, and the amount of fresh steam needed would be the volume displaced by the piston up to the point of cut-off, the same as if there were no clearance. It is not practicable to build an engine without any clearance, owing to the formation of water in the cylinder due to the condensation of steam, particularly when starting the engine, as water is practically incompressible. Some part of the engine would be broken when the piston reached the end of the stroke if there were no clearance space for the water to collect in. Usually the cylinder head would be blown off. Neither is it practicable

to compress to higher pressure, as a general rule, for that causes too great a strain on the engine. Automatic cut-off, high-speed engines, with shaft governors, generally compress to about half the boiler pressure and have a clearance of from 7 per cent. to 14 per cent.

How would you equalize your clearance?

We would disconnect our cross-head, and proceed to get our striking point. We will push our piston to the end of the cylinder until it strikes the head, then make a mark on the glide even with the end of the shoe of the cross-head. Now we will push our piston to the opposite end of the cylinder until it strikes the head, and mark on guide even with the end of the shoe of the cross-head. This will give us our striking points. Now we connect our engine again, turn engine over on dead centre, make a mark at end of shoe, and measure to the striking point. Now we turn engine on opposite centre, make another mark at end of shoe of the cross-head. Take the measurement to striking point. This will show if there is any difference between the clearance of the head end and the crank end. If there is any difference, it would be caused by keying up on the cross-head or crank end of connecting rod. If key, gib and strap connections, this would shorten. To adjust, put shim between our stud end and our crank-pin box or cross-head box. The shim should be one-half of the thickness of the difference in clearance.

Cut-off.

What is the range of cut-off for a piston stroke?

The range of cut-off is that part of stroke it is possible for the engine to cut off in. Engines having a single eccentric, it is from zero to two-fifths stroke. Engines with a double

eccentric, one-half stroke. In starting up these engines, take steam full stroke until they come up to speed.

How do you equalize cut-off?

To equalize cut-off, put engine governor in running position and adjust trips till valve is tripped at same point at each end. In setting the valve, governor rests on a collar or a stop-motion pin. After engine is started, stop motion is removed. This is so, if the belt breaks, the governor drops to the lowest position, and safety-cams should prevent valve being picked up and the engine from racing.

How do you find the proper length of eccentric rod?

To find the proper length of eccentric rod, roll eccentric to extreme of travel, and see if carrier arm and wrist plate works at an equal distance each side a centre line.

What is the usual length of connecting rod?

The usual length of connecting rod is six times the length of the crank.

Why dces the piston travel faster on the head end?

The piston travels faster on the head end than on the crank end. This is corrected on a single-valve engine by giving more lead on the crank end, and is due to the angularity of the connecting rod.

The motion of the crank is steady, but the motion of the piston is not, as it stops at the end of the stroke, and moves faster at mid-stroke. The crank end of connecting rod moves in a circle instead of the straight line that the cross-head moves in, and for this reason the crank is half-way over, or vertical, when the piston is at more than half-stroke.

PISTON.

Describe a piston.

There are two kinds, a solid and a built-up piston. The solid piston is of one piece, with grooves in its circumference to receive the packing rings. These "packing rings," or spring rings, are cast iron. They are thicker at the bottom and split, being a little larger than the cylinder. When in place, they spring out enough to keep the piston from leaking. If weak, they may be tightened by peening evenly inside with a ball-peening hammer. To remove piston rings, raise them carefully with a thin piece of tin all around, and, when out of the grooves, slide them off.

A built-up piston consists of a spider, bull-ring, adjusting bolts, and packing rings. The spider is attached to the piston rod with a nut or key. The bull-ring is a solid ring and surrounds the spider. Between the spider and the bull-ring are the adjusting bolts. These adjusting bolts are to raise the centre of the spider to keep it central in the cylinder, as the cylinder wears. The piston rod is tapered or has a shoulder on it, and is secured to the piston with a nut. Before removing the piston, see that it is marked. If not, mark on the rod and cross-head, so it may be put back at the same point. Also see that the end of rod does not drop into cylinder as it comes off the stuffing box, for it will scar the cylinder. To adjust the piston, measure from counter-bore to centre of piston rod and adjust with adjusting bolts. Measure from counter-bore because it never wears. The counter-bore is so that the piston will ride over and prevent wearing shoulders in cylinder.

Do not allow the packing to become hard and dry in the stuffing boxes, as under such circumstances it has a tendency

to cut and flute the rods. To pack piston rod, remove the old packing. There is a specially prepared packing, made of canvas and rubber. When the gland is drawn up with bolts, be sure and tighten squarely and not too tight at first.

How can you tell if a piston is tight?

Place your engine on head end centre, and open opposite drip. If it leaks, steam will come out.

To see that a piston is steam-tight, put piston on crank-end dead centre, open steam valve, and with cylinder head off see if steam blows past piston or out of drips.

How do you adjust piston?

To adjust the piston, measure from counter-bore to centre punch-hole on a piston rod, and adjust with adjusting bolts. Measure from counter-bore because that part never wears.

What is the object of the built-up piston?

A built-up piston is used, so that, as the bottom of the cylinder wears, these springs bear against the packing rings and take up the wear. When piston is screwed in the cross-head, there are two holes tapped into the piston head. Put in long bolts and a bar, and turn piston in or out.

What makes the piston rod heat?

The piston rod must run centrally through the stuffing box at all times. If not, it will bind in the stuffing box and heat. The cross-head may be raised or lowered by bolts and wedges on the shoes of the cross-head. With a solid cross-head the guides may be shimmed.

The Connecting Rod.

What is the connecting rod?

The connecting rod connects the cross-head with the crank. There are two kinds of connecting rods, the strap end and the solid end. The straps are secured to the stub ends either

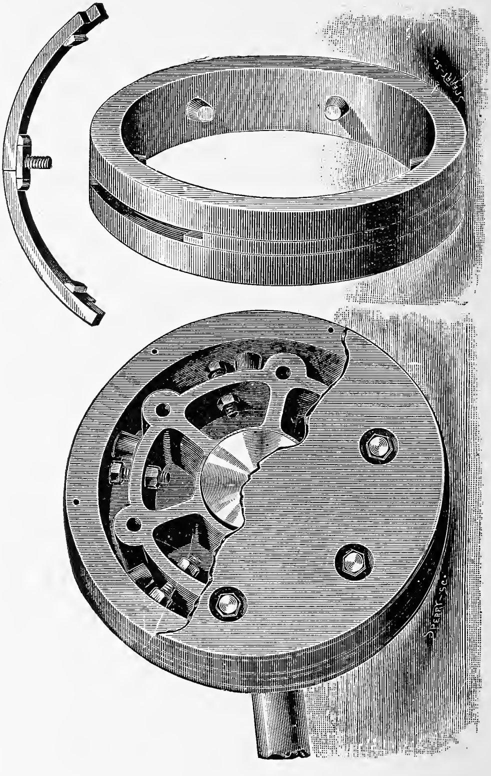


Figure 27.

by bolts or gibs, and the brasses are set up by a taper key or wedge.

What is meant by angularity of connecting rod?

The angularity of a connecting rod is a term that applies to its path of motion, which is during all parts of the stroke, except on the dead centre, at an angle to the line of engine centres. The crank-pin end of connecting rod moves in a circle instead of a straight line the cross-head moves in. The piston travels farther when on the head end than on the crank end, due to the angularity of the connecting rod.

The direction of the variation is to cause the point of cut-off to occur later on the stroke, when the piston is moving from the head end of the cylinder towards the crank.

The amount of variation caused in the two points of cut-off by the connecting rod depends upon the proportion that exists between the length of the crank and that of the connecting rod, which is greater than that of the crank.

Solid-end Rod.

What is a solid-end rod?

Places for boxes are cut out of the side of the rod. A flange is placed on boxes to hold them in place with screws. On solid-end rods a wedge instead of a key is raised by drawing a bolt.

What is the effect of keying up on a solid-end rod?

Keying up lengthens the rod.

You will find a number on the key, gib, strap, and end of rod corresponding, and, when these parts are put together right, the same number will appear on the same side. In keying up a key-and-gib end, the key bears against the end of the slot in the rod and against the tapers of gib. In keying up, be sure that the boxes do not touch. This would be

brass-bound, also key-bound; that is, where the key is down so far it fills the slot in the strap and cannot be driven further. This shortens the connecting rod. Some straps are bolted on instead of having a gib. In this case the key bears against the bevelled outer end of rod on one edge and the other bears against the brasses, and in keying up moves the brass toward the pin: this lengthens the connecting rod. Some straps are bolted on instead of having a gib. In this case the key bears against the bevelled outer end of rod on one edge and the other bears against the brasses, and in keying up moves the brasses toward the pin. This lengthens the connecting rod.

Key, Gibs and Strap.

The key, gib, and strap are the most simple and effective mechanical devices employed for securing the connecting rod of steam engines to the wrist and crank pins and taking up the lost motion in the boxes, as they possess sufficient strength without extra weight of material, and facilitate quick and easy adjustment. Some make the thickness of both straps on the connecting rod one-half the diameter of the crank pin and their width about three-quarters the length of the pin; others make the width of their straps three times their thickness and the area of the cross-section at the mortise equal to the area of the smallest part of the connecting rod; while others still make them equal in strength to the weakest point in the piston rod, which they undoubtedly should be in any case.

What is the most common kind?

The most common kind is the key, gib, and strap. The connection between connecting rod and wrist pin or crank pin is made through removable brasses, adjusted to take up the

wear. The strap holds the brasses in place: it is slotted to receive the gib and key. The gib is wedge shape, and has lips on it to hold the strap on, and the key is tapered to take up wear. Some straps are bolted on, instead of a gib. In this case the key bears against the tapered end of the rod instead of on the end of the slot in rod.

What is the effect of keying up a key, gib, and strap?

Keying up on a key, gib, and strap-end rod shortens the rod. This changes the clearance in the cylinder, making run nearer the crank end than the head end. By putting a piston shim between the strap and the box merely raises the key. Now, if you do not wish to change the clearance, put a shim between the end of the rod and box. This lengthens the rod.

Key Room.

What would you do if crank pin or cross-head had run out of key room? How would you proceed to key either of these boxes?

In a case of this kind the slot in the strap has moved ahead until it comes even with the slot in the stub end. The key cannot draw it up any more. Now, if we should place a shim between our stub end of rod and our brass, it would give us the desired effect, but this would change our clearance in the cylinder. So to avoid affecting our clearance, which is all right, we will place a shim between our strap and our brass. This will bring our strap back, and our key can take up anew.

Eccentric.

What is an eccentric?

An eccentric is substantially a crank with its pin enlarged in diameter so as to enclose the shaft on which it is placed.

It gives exactly the same motion that would be obtained from an ordinary crank of equal throw.

What is meant by throw of the eccentric?

The term "throw of eccentric" is understood to be the same as the travel it imparts to the valve, and which is understood to be equal to the width of both steam ports with the lap added.

What is meant by angular advance of the eccentric?

Angular advance of the eccentric means the angle at which it stands in advance of that which it would occupy if the valve were in the centre of its travel and the crank at its centre.

The eccentric consists of what?

The eccentric consists of a strap, bolts, and rod. The strap conveys the motion of the eccentric to the eccentric rod. The strap must not bind the eccentric, or it will heat. If loose, it will pound. The eccentric is flanged to receive the strap.

How do you take up the wear on the eccentric?

By putting in a thinner shim.

What makes the eccentric heat up?

If stuffing box on valve stem is too tight, bringing heavy load on eccentric, eccentric may heat. The eccentric must be kept well oiled. The eccentric is sometimes called a cam, which is erroneous. A cam is used to obtain a motion different from that which can be obtained from a crank. The term "cam," when used without qualification, is indefinite, and conveys no impression of its precise form of function.

The position of the eccentric ahead of crank will be 90 degrees plus the lap and lead. In following the crank, it will be 90 degrees minus the lap and lead.

An engine having a single valve, or where the valve is controlled by the governor, takes care of admission as well as

the cut-off; an engine having a slotted eccentric is used where the governor is between the shaft bearings where an eccentric must be used. Weights move in as the load increases, and eccentric moves away from the shaft, or an overhanging pin is used where the wheel is outside the bearing of the shaft, a connecting rod from this pin operating the valve.

A loose eccentric is used only with a riding cut-off engine, where the lead is taken care of by the fixed eccentric, the governor controlling only the cut-off. These governors are called fly-wheel governors because the governor is in the fly-wheel and acts directly upon the eccentric that moves the valve which positively opens and closes the steam valve, automatically changing the cut-off according to load. They operate a single balanced slide valve or a piston valve. The weights fly out as the speed increases, throwing a slotted eccentric nearer to the centre of the shaft, decreasing the travel of the valve and making an earlier cut-off.

The eccentric is not fastened to the shaft, but is connected by links to weighted levers, pivoted on the arms of the governor wheel, and these weights are controlled by springs. As the speed increases, the centrifugal force of these weights overcomes the tension of the springs, and the weights fly out, and the links throw the eccentric toward the centre of the shaft, changing the throw of the eccentric and the travel of the valve, and making an early cut-off. When the load is increased, speed decreases, and the reverse of this operation takes place. The speed of these engines is changed by changing the tension of the spring or adding weights to the governor.

There are four types of these engines. The loose eccentric fits the shaft, and can be rotated around it. A slotted eccentric has a slotted hole in it, where it surrounds the

shaft, and can be swung across the shaft, also an overhanging and double eccentric.

With single valve the compression changes with every change in load, increasing with a light load. When the load is lighter, cut-off is earlier, compression greater, and release earlier. With heavy load, cut-off is later, compression less, and release later.

The object of using a slotted eccentric is to keep the lead constant for all changes in cut-off.

Compound Engine.

To obtain the advantages of a high pressure and at the same time avoid the loss due to cylinder condensation as much as possible, the steam may be allowed to expand in two or more cylinders. When the expansion takes place in two cylinders, the engine is said to be compound. If the expansion takes place in three cylinders, the engine is said to be triple expansion, and, in four cylinders, quadruple expansion.

There are two types of compound. When one cylinder is placed behind the other, the engine is called a tandem compound. When the cylinders are placed side by side and the piston rods are attached to separate cross-heads, cranks 90 degrees apart, the engine is called a cross compound. If both pistons are attached to the same cross-head, the engine is called a twin compound. The engines may be condensing or non-condensing.

In any compound engine, without a receiver, the two pistons must begin and end their stroke at the same time, and the two cranks must be together or placed 180 degrees apart.

Receiver pressure is usually 10 to 15 pounds, and may be increased by cutting off earlier in the low-pressure cylinder or by cutting off later in high-pressure cylinder.

Cutting off earlier in low-pressure cylinder makes that cylinder do more work. Steam taken in is of a higher pressure, and makes the high pressure do less work by putting more back pressure on that cylinder.

To make the engine do more work, cut off as late as you can, also cut off later on low-pressure cylinder, and add live steam to keep receiver pressure up. This is accomplished by taking live steam through a reducing valve from the boiler.

If high-pressure cylinder breaks down, disconnect that side, and run with low-pressure cylinder by opening by-pass to cylinder.

If the low-pressure cylinder breaks, disconnect that side, and let the steam blow through, and run the engine with high pressure.

To start the engine when the high pressure is stuck on the centre, open by-pass to cylinder and pull the high pressure off with the low-pressure cylinder.

To start when the load is heavy, let the steam into the receiver and get the power of the low-pressure cylinder with live steam. If one end of the low-pressure cylinder is disabled, block the valve, shut that end, and run the engine with high-pressure cylinder with one end of low pressure, then make the cut-off as late as possible on low pressure to keep receiver pressure down. Steam in the receiver is sometimes superheated with live-steam. Receiver has a drain pipe to carry off condensed steam.

A receiver is supplied with live-steam connection from boiler through a reducing valve.

Receiver has a relief valve to prevent pressure getting too high. Receiver has a drip pipe, to drain the water out.

If boiler pressure is raised and load added to the engine, enough to keep the old cut-off, then steam enters the re-

ceiver at a higher pressure, and a greater weight will flow in, and, unless low-pressure cut-off is made later to correspond, the receiver pressure would rise; and, again, if we opened a separate live-steam pipe into receiver and added a supply to that coming from high-pressure cylinder, receiver pressure cylinder is cut off as late as possible, and if it is desired to get more work out of low-pressure cylinder by a later cut-off which would reduce receiver pressure, this pressure is then kept up by the supply of live steam to it.

Compound engines are used for economizing in order to use steam of high pressure and expand it more. To divide the work of the high-pressure steam between the cylinders, and to get less cylinder condensation, a great deal of the hot steam is condensed when it enters the cylinder, and this is turned again into steam during the exhaust stroke, and passes out of exhaust pipe without doing any work.

The ratio of expansion in a compound engine is the number of times the steam is expanded.

Rule.—To find the ratio of expansion in any cylinder, not considering clearance, divide the total cylinder volume by volume of steam in the cylinder up to the point of cut-off.

Example.—An engine having a cylinder volume of 10 cubic feet cuts off at a point where the volume of steam is 6 cubic feet. How many times does the steam expand, or, in other words, what is the ratio of expansion?

10 cubic feet = volume of cylinder.
6 cubic feet = volume up to cut-off.

$$10 \div 6 = 1.66.$$

Rule.—To find the ratio expansion between compound cylinders, square the diameter of each cylinder, and divide the

square of diameter of low pressure by the square of diameter of high pressure.

Rule.—To find the total ratio of engine, not considering clearance, divide the total cylinder volume of high-pressure cylinder by the volume of steam in cylinder up to the point of cut-off.

Divide the volume of low-pressure cylinder by the volume of the high-pressure cylinder, and multiply these two products.

Example.—A compound engine having cylinders 15 × 24 and 40-inch stroke cut-off in high-pressure cylinder, at 9 inches what is the ratio of expansion, and total ratio of engine, not considering the clearance?

15-inch cylinder area = 176.
40 = inches stroke.
7068.0 = total cylinder volume in cubic inches.

176.7
9 = inches point of cut-off.
1590.3

1590)7068(4.44 = ratio of expansion in high-pressure cylinder.
6360
7080
6360
7200

area 15-inch cylinder = 176.7
40
7068.0 = volume H. P. cylinder.

area 24-inch cylinder = 452.4
40 = inches stroke.
18096.0 = volume L. P. cylinder.

```
7068)18096(2.5=ratio L. P. to H. P. cylinder.
     14136
     -----
      39600
      35340
      -----
                 4.44
                  2.5
                 ----
                2220
                888
               ------
               11.100=total ratio of engine.
```

VALVES.

Describe action of a D slide valve.

The various events which are governed by the D slide valve of a steam engine are as follows:—

The live-steam period is that during which steam is admitted from the steam chest into the cylinder, and the steam admitted during this period is termed live steam.

The point of cut-off is that at which the valve closes the steam port and the admission of steam into the cylinder is stopped. Hence the cut-off is at the end of the live-steam period.

The period of expansion is that during which the steam is allowed to expand in cylinder, and therefore begins at the point of cut-off, ends at the point of release.

This point of release is that at which the valve opens the port and permits the steam to escape. The point of compression is that at which the exhaust port is closed, which occurs before the piston has reached the end of its stroke. The steam that has not passed out of the cylinder is therefore compressed, the compression continuing until the valve opens for the lead.

What is lead?

The lead of the valve is the amount the port is open to the live steam when the crank is on the dead centre. The point of admission is the amount that the port opens for the live steam to enter, and it follows that the lead and compression both act as a cushion, arresting the motion of the piston when it reaches the end of the stroke. Cushioning begins, however, at the time the exhaust port is closed enough to arrest the escape of the steam, while compression begins when the valve has closed the exhaust port.

What does a D valve do?

A valve has four things to do each stroke: lead, cut-off, release, and compression. Each edge of the valve does two of these things. More lead is obtained by making steam valve open sooner in the stroke. Earlier cut-off is obtained by making steam valve close earlier in stroke. More compression is obtained by making exhaust valve open earlier in the stroke. This makes the exhaust valve close earlier. Eccentric slipping makes all things late.

What is the effect of setting the eccentric ahead?

To make all of the events earlier. With reference to the stroke, it makes admission earlier, and gives more lead. Cut-off and release are earlier, and the exhaust valves close earlier, giving more compression. Outside lap makes admission later and cut-off earlier, the lead is diminished. If the eccentric is ahead, to give the same lead with the greater lap, we shall have a still earlier cut-off, earlier release and compression, and an admission as early as it was before. With the eccentric set back, the effect is the valve opens later, giving less lead, cuts off and releases later, the exhaust ports are closed later, giving less compression. The lap reduces the rapidity and diminishes the range of cut-off.

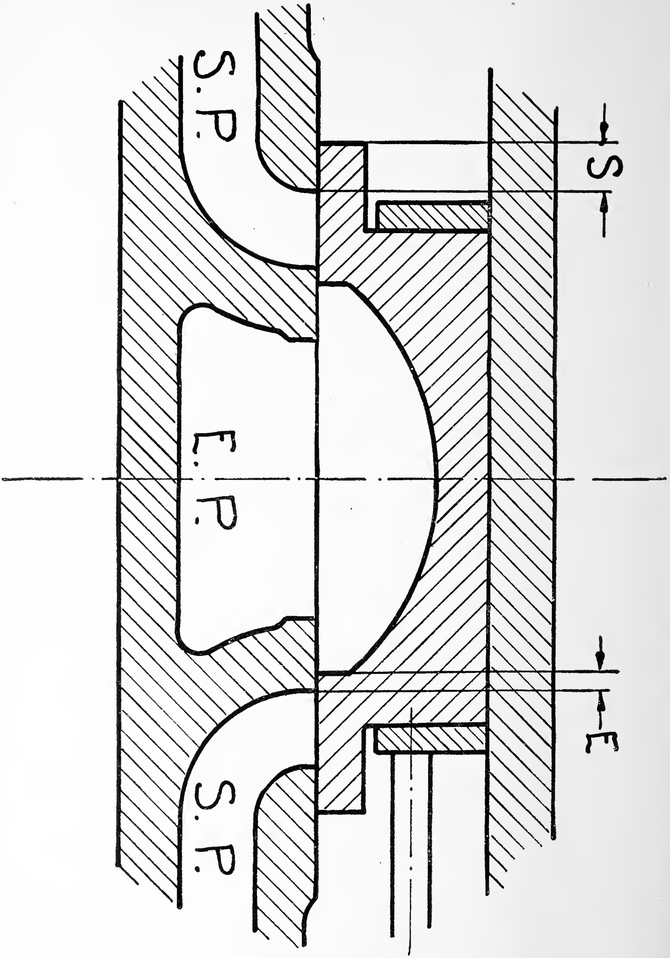


FIGURE 28.

Showing the valve in mid-position.
S = steam lap.
E = exhaust lap.
S. P. = steam ports.
E. P. = exhaust ports.

What is lap on the valve?

The term "lap on the valve" denotes the amount the edges of the valve extend over the ports when the valve is in the centre of its travel. If a valve has $\frac{5}{8}$-inch lap, it is understood to extend $\frac{5}{8}$-inch beyond the ports when placed centrally over them. The object of lap is to secure the benefit to be derived from working steam expansively. Lap on the steam side is termed outside lap, while lap on the exhaust side is termed inside lap, on a common slide valve.

What is the object of lead on the valve?

The object of lead is to enable the steam to act as a cushion against the piston before it arrives at the end of the stroke, to cause it to reverse its motion easily, and also to supply steam of full pressure to the piston the instant it has passed dead centre. It varies in different engines from $\frac{1}{32}$ to $\frac{3}{16}$ of an inch without regard to size or kind. The higher the speed and the more irregular the work, the more lead will be required for any engine.

Lead on the steam end is a term applied to the amount of opening the valve has at the end of the cylinder into which the steam is entering. Lead on the exhaust end means the amount of opening the valve has on the end from which steam is escaping. The name applies alternately to each end of the cylinder.

How do you get additional compression?

Advance the eccentric slightly or lengthen exhaust-valve rods. This gives lap on exhaust valves, also more compression, but makes the release of steam later. Exhaust lap on that account very limited. For fast-running engines additional compression is necessary, but the range of cut-off must not be reduced, as it lessens the power of the engine.

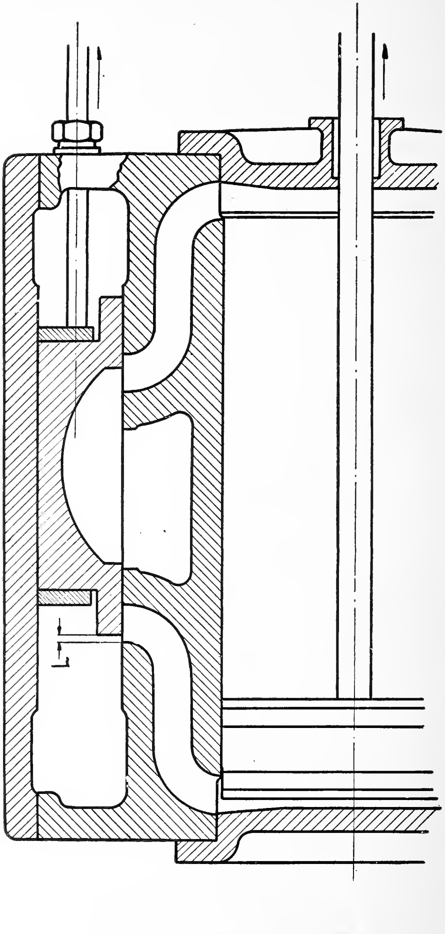


FIGURE 29.
Showing piston at commencement of stroke and relative position of valve.
L = lead.

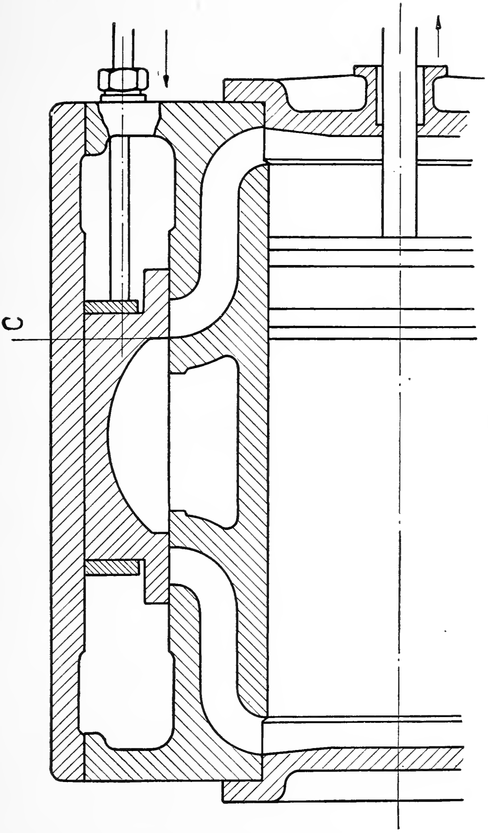


FIGURE 30.
Showing piston and relative position of valve at point of compression C.

Why do you give a valve lap?

Giving a valve lap is intended merely that we may keep the port closed until the engine is on the centre. The lap on valve is the amount it overlaps the port when the valve is in mid-throw. Lap does not apply to the amount that valve laps, if the valve is not placed so as to overlap alike on both ends.

Advancing the eccentric makes every action of the valve take place earlier in the stroke.

Adding steam lap and then setting the eccentric ahead causes the port to be opened less and the cut-off to occur earlier.

Adding exhaust lap will cause the release to be later, and the exhaust to close earlier. This gives greater compression.

Taking away steam lap causes the valve to open the port earlier and wider, resulting in a later cut-off. Taking away same exhaust lap causes the exhaust port to be opened earlier and to close later, giving less compression.

What is unequal steam lap?

Exhaust lap is the amount the exhaust cavity overlaps the bridge. Unequal steam lap is given to cause the point of cut-off to occur at equal points in the piston stroke. There is more steam lap at the head end than at the crank end of the valve; but unequal lap could be given in order to greatly vary the point of cut-off of the two-piston strokes. If such is desired, unequal exhaust lap may be given to equalize the point of release or to equalize the point of compression.

What is the eccentric angular advance?

The steam valves are given lap, and the eccentric angular advance on account of the exhaust valves. In case the exhaust valves had no lap, release and compression would occur at the end of the stroke instead of before the end, as it should to obtain good distribution. Since the exhaust valve must have lap and there is but one eccentric, the steam valve must

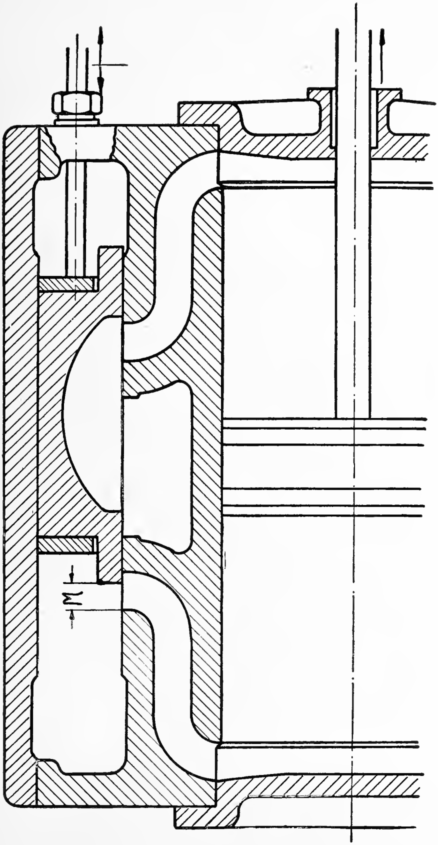


FIGURE 31.
Showing piston at mid-stroke.
Valve at this point begins to travel in other direction.
Position shows valve giving maximum port opening M.

have lap also. Therefore, the eccentric must have considerable angular advance.

Unequal steam lap is given to cause the point of cut-off to occur at equal points in the piston stroke. Unequal exhaust may be given to equalize the point of release or to equalize the point of compression.

Which is the head end of cylinder?

The head end of the valve, or the cylinder, is that which is farthest from the crank-shaft end, or that nearest to the crank shaft, being termed the crank end.

What is cushioning?

Cushioning begins at the time the exhaust port is closed enough to arrest the escape of the steam, and compression begins when the valve has closed the exhaust port.

How do you find the area of steam port?

Rule.—Multiply the length of stroke in feet by the number of strokes per minute, and this product by the area of the piston. Divide this last product by 6000, which is the velocity of live steam in feet per minute.

Example.—What should the area of steam port be for a 10 × 12 engine, making 300 revolutions per minute?

```
    1=12-inch stroke.
  300
  ---
  300
    2=strokes in one revolution.
  ---
  600=number of strokes per minute.
78.54=area 10-inch cylinder.
-----
 2400
3000
4800
4200
--------
47124.00
```

velocity of steam $=6000)47124(7.85=$ area of port in square inches.

$$\begin{array}{r} 42000 \\ \hline 51240 \\ 48000 \\ \hline 32400 \end{array}$$

The port opening is designed for a constant speed of piston. But it is a fact that on the head end the piston moves much faster than on the crank end. When piston starts from crank end, it is slower and moves more rapidly after mid-stroke. The movement is first a rapid one and then a slow one. This is due to the angularity of the connecting rod.

The object of giving compression is to form a cushion for the piston, to stop it and carry it easily over the dead centre. The piston and its cross-head comes to a full stop twice in every revolution.

Why do you use a slotted eccentric?

The object of using a slotted eccentric is to keep the lead constant for all changes in cut-off.

D Valve.

The ordinary D slide valve is subjected to a great pressure by the steam on its back. Thus, if a large engine, the valve is, say, 10 inches long by 12 inches wide, and the boiler pressure is 90 pounds. The pressure on the back of the valve is $10 \times 12 \times 90 = 10{,}800$ pounds. This great weight causes the valve seat to wear very fast.

To obviate this, a balanced valve is employed. The plate and valve is ground to a perfect fit, and no steam can get on the back of the valve. The flat plate is called a pressure plate. The valve slides under this with a perfect fit. There is

a spring pressing on the valve to keep it to its seat. The valve would still be unbalanced from beneath, steam filling the steam ports, pressing upwards against the valve, and forcing it against the pressure plate.

To counteract this, recesses having the same width and length as the steam ports are cut into the pressure plate, and steam is allowed to enter each, and they are exactly opposite.

What other advantage in a balanced valve and eccentric?

The governor parts are made much lighter.

Why do you cut off steam in a cylinder?

The object is to use steam economically by cutting off the supply to the cylinder at such a point that, when steam is exhausted, it has expanded until there is no pressure in it.

TO SET THE COMMON SLIDE VALVE.

If the principles are understood, there should be no difficulty. The object is to make the valve travel equally each way from mid-position. This is what is meant by squaring the valve.

First take off the steam-chest cover, then loosen the eccentric and revolve to extreme throw on head end, and note how much the valve laps over the port. A good way is to mark with a pencil, then revolve the eccentric to the opposite throw, note the lap on this end, and, if you find that the valve has travelled, say, $\frac{1}{2}$ inch farther on this end, shorten the valve spindle by nuts one-half of that amount, which will be $\frac{1}{4}$ inch. This will pull the valve $\frac{1}{4}$ inch towards the desired end and cause its displacement to be equal each way.

Next revolve the engine to head-end dead centre, and give the eccentric the proper angle of advance. Give the valve $\frac{1}{32}$ lead, fasten the eccentric at this point, revolve the en-

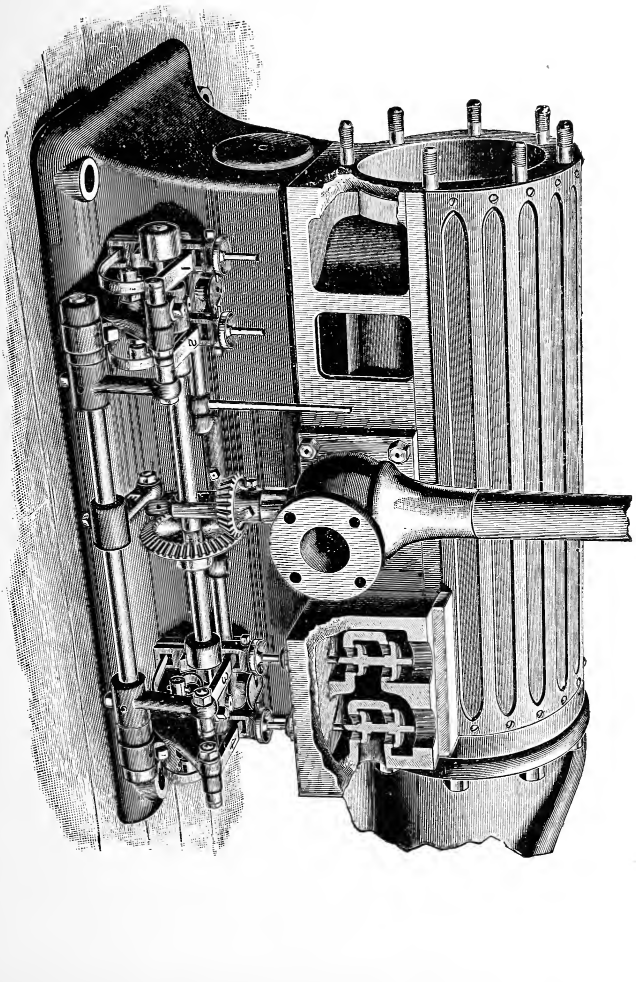


FIGURE 32.

gine to opposite throw dead centre, and see if you have the same lead on that end. If not, adjust by nuts on valve stem. Now, if you find that you have no lead, advance your eccentric till you have the proper lead. With this properly done, your valve is set.

The indicator should be freely used, and changes made to correct the defect shown on cards.

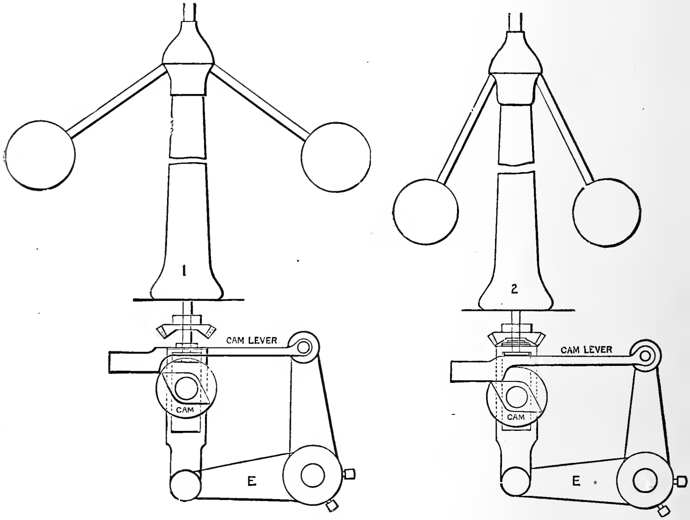


FIGURE 33.
GOVERNOR AND CAMS.

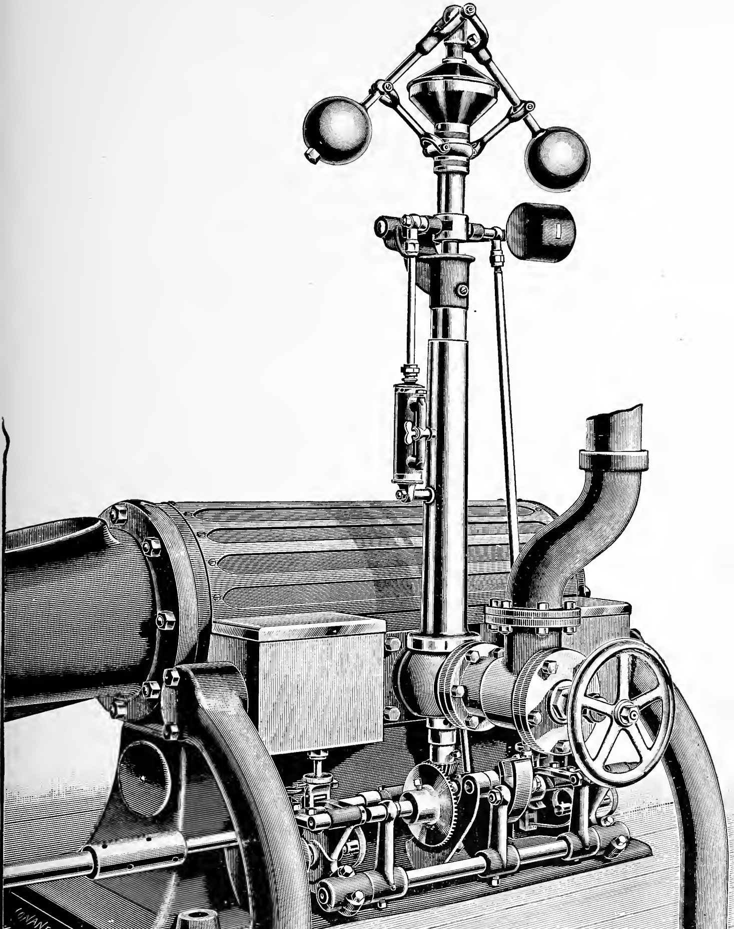


FIGURE 34.

VALVE SETTING FOR THE PUTNAM ENGINE.

What peculiarity is noted on a Putnam engine?

It has poppet valves, balanced type, the two inside valves for steam and the two outside valves for exhaust, The ports in this engine are extended below the cylinder bore, so that the raising of valves by means of the trip shaft can be accomplished with one motion of this shaft.

How are the valves operated?

Each valve is operated by a separate cam attached to cam shaft, which in turn acts upon a lever on which the valve stem bears. Each valve has two seats. The cam shaft is driven by gears from the main shaft.

How do you set the valves of this engine?

Raise the governor balls as high as they will go, hold them in this position, then push in the steam valve levers far enough to allow the cams which operate them to be turned around, clearing the valves without lifting the valve.

When the levers are in this position, tighten the set screw in the rocker arm at the bottom of the regulator, then lower the balls to their running position. See that the set screw on the side shaft is screwed up tight. Put the crank on dead centre near the cylinder. Beginning at steam valve No. 2 (see cut), on head end make a scratch on valve stem $\frac{1}{16}$ inch below the packing box, then turn the steam cam by hand in the direction indicated until it strikes the lever, raising same and valve stem $\frac{1}{16}$ of an inch, then make the set screw in cam tight when the valve is raised to the height as indicated by line.

Next, while the crank is in the same position, take exhaust cam No. 4,—this is the outside nearest to the crank,—set that valve in the same manner as the steam valve, excepting that the scratch line should be made $\frac{3}{16}$ of an inch below the

packing box of valve stem, so as to raise the valve $\frac{3}{16}$ of an inch, at which point tighten as before.

Next turn the fly-wheel in the direction it is to run till the crank reaches dead centre. Then set steam valve No. 3 in the same manner as No. 2, excepting that you measure $\frac{1}{32}$ of an inch, letting the valve raise $\frac{1}{32}$ instead of $\frac{1}{16}$ of an inch without moving the crank. Take exhaust cam No. 1 and set the same $\frac{3}{16}$ of an inch, in same manner as valve No. 4. Make set screws in cam tight.

The caps to bearings of rocker-arm shaft which connect cam levers 2 and 3 are lined with leather, and are made so for the purpose of giving more or less friction to the shaft. In case the regulator becomes unsteady, tighten up slightly the two cap bolts on rocker-arm shaft.

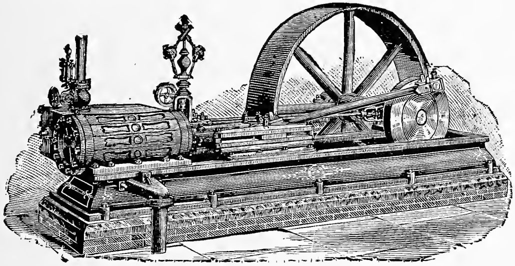


FIGURE 35.
RIDING CUT-OFF ENGINE.

RIDING CUT-OFF ENGINE.

What is the principal feature about a riding cut-off engine?

It has two valves and two eccentrics.

What is the function of the main valve?

It regulates the admission, release, and compression.

What is the function of the rider valve?

It regulates the cut-off only, and has nothing to do with the lead, release, or compression.

In what relation to the crank is the main valve eccentric set?

About 90 degrees ahead of the crank.

In what relation to the crank is the rider eccentric set?

About 180 degrees ahead of the crank, or about 90 degrees ahead of main valve eccentric.

How do you set the valve on a riding cut-off engine?

Loosen the eccentric, put it at extreme throw, and place valve square over the ports. Then mark with a pencil on the valve seat, and turn eccentric to the other extreme throw and note mark. Then, if there is a difference, divide that difference, place your valve at that point, by the nuts on valve stem, and, if you are correct, the valve will travel an equal distance over the ports. Then put your engine on dead centre, and advance your eccentric till there is $\frac{1}{32}$ inch lead. Then place your rider eccentric with your main eccentric, and place your valve square over the main valve, turn the engine over, and, if your work is right, the valves will travel together. Place the engine on dead centre, then measure off, say, 3 inches on the guides at each end, turn engine forward that amount on stroke, then turn the rider eccentric ahead till rider just closes the port. Now put your engine on other stroke the same way, and see if cut-off is alike. If not, adjust by nuts on valve stem by dividing one-half the distance.

What is a left-hand engine?

Standing at the cylinder end and facing the shaft, the fly-wheel is on the left side.

What is a right-hand engine?

Standing at the cylinder end and facing the shaft, the fly-wheel is on the right side.

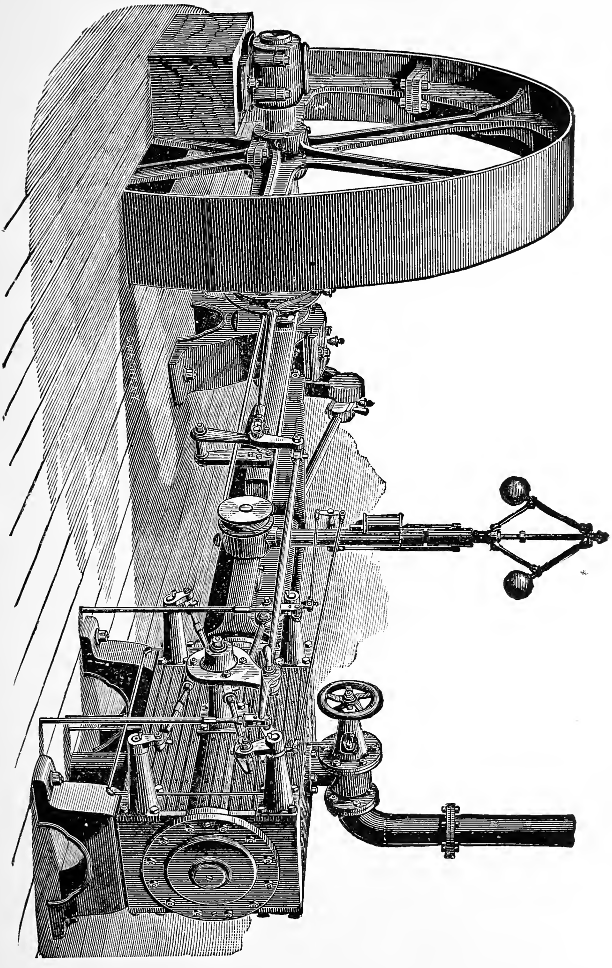


FIGURE 36.
HARRIS-CORLISS ENGINE.

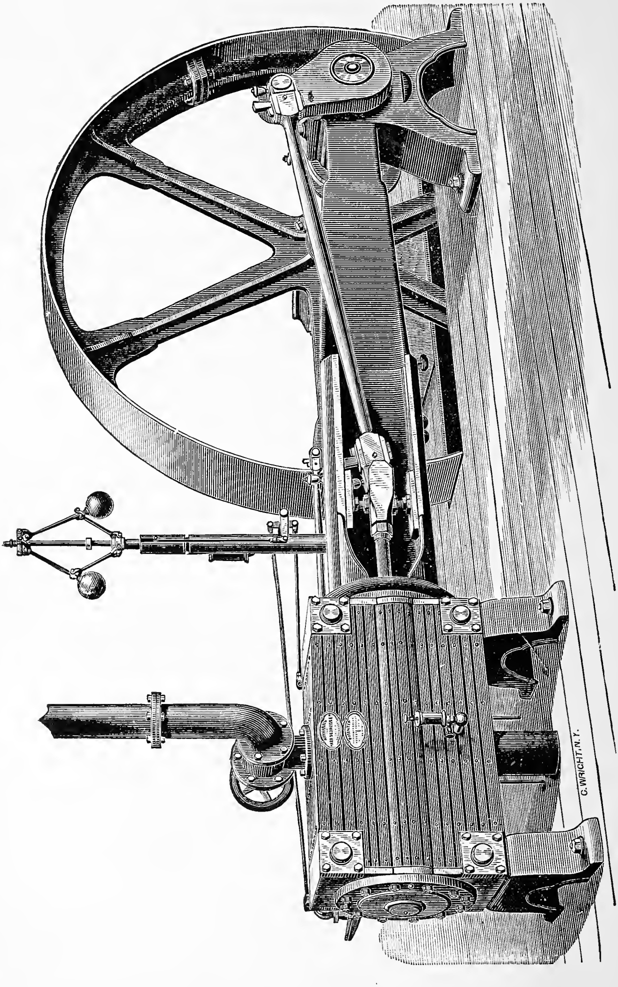


FIGURE 37.
HARRIS-CORLISS ENGINE.

CORLISS ENGINE.

The Corliss valve gear is used in a large number of engines. It has four separate and distinct valves. Two of these connect directly with the steam chest, and are called steam valves. The other two valves connect direct with the exhaust chest, and are cylindrical in form and extend across the cylinder above and below.

There is a disk or wrist plate, which is made to rock upon a stud by the eccentric rod connecting it with an eccentric on the crank shaft.

There are four valve stems, which are connected to bell cranks. From the end of these cranks adjustable connecting rods, commonly called right and left, are made fast into wrist plate. Any one of the valves regulates independently of the other. As a consequence of this arrangement, the steam and exhaust valves have entirely independent movements, and the inlet ports may be suddenly opened full width by the quick movement of the steam valve. The advantage of this valve gear is that it permits an earlier cut-off with a greater range, a more perfect steam distribution, and a smaller clearance space than is attained with the plain slide valve.

Some valves have a T-headed valve stem, fitting into a slot in the end of the valve, and these valves can be removed without removing the valve stem. The exhaust valve differs in appearance from the steam valve.

There is a single eccentric and a double eccentric Corliss. A single has one wrist plate, the double two wrist plates. There is an eccentric rod, and a hook rod connecting rocker arm and wrist plate, and is lifted off in starting engine, so as to work the valve by hand. The crab-claw, or hooking

latch, is held against the block on valve arm by a spring. When it moves forward, this crab-claw is intercepted by the cut-off cone, which disengages it from the block, and valve is then closed by a dash-pot. Right and left connections connect wrist plate and the valves, the governor balls rising or falling with the change of load, so as to disengage valve early or later in the stroke, according to the load. When governor balls rise, the cut-off is earlier.

The Corliss engine is an automatic cut-off engine.

How do you start a Corliss engine?

In starting a Corliss engine, make sure that the governor is on the stop motion, so that the valve will be picked up when the engine comes up to speed.

VALVE SETTING FOR CORLISS ENGINES.

First look over the valve gear, and take up all lost motion. This is quite essential.

Remove the valve chest bonnets on the side of the engine. You will find marks representing the edge of valve, also the edge of port.

Then centralize the various parts, and equalize their movements.

Roll the engine over, place piston on the dead centre. Put the governor in the average running position, loosen up the eccentric, and turn on the shaft to the extreme travel farthest from the cylinder, and wrist plate is at extreme of travel. Note mark on the hub and wrist plate. Roll the eccentric to opposite extreme of travel, and see if this mark on wrist plate corresponds with mark on the hub. If not, adjust eccentric rod till the centre mark on the wrist plate travels an equal distance each side of a centre mark on the hub.

Place wrist plate in middle position, and hook up steam valves on both ends. Then adjust right and left, so steam valves will lap $\frac{1}{8}$ inch or more, according to size of engine. At the end of valve on the side of engine will appear a mark on the valve showing the edge of valve and two marks on the seat, the lower mark showing the edge of the port, second mark representing the amount valve should lap over the steam port. Be sure wrist plate is in central position, and adjust steam valves. Then place exhaust valves line and line.

Now advance eccentric till the valve has $\frac{1}{32}$ inch lead. Fasten the eccentric to the shaft at this point. Roll the engine over to the head-end dead centre, and see if you have the same lead on that end. If not, adjust by the right and left.

On most Corliss engine governors will be found a stop device, sometimes in the form of a loose pin or a removable collar. This device is for the purpose of preventing the governor from reaching its lowest position, for, when it reaches the latter position, the valve should not hook on. Should the governor belt break, the governor would stop, and reach its lowest position on the spindle; and, as the valves cannot hook on when in that position, the admission of steam to the cylinder is entirely shut off, and the engine will come to a stop.

From the foregoing the stop at the lowest part of the governor spindle should be removed (as otherwise rendered inoperative as soon as the engine has attained full speed), and should again be placed in active position when about to stop the engine.

We will again turn our attention to the exhaust valves, this time for the purpose of adjusting them for compression, as the exact amount can only be determined satisfactorily

by trial. We will say that our engine is to have $2\frac{1}{2}$ inches' compression; that is, the exhaust valves must be set so as to close the exhaust port when piston is within $2\frac{1}{2}$ inches of the end of the stroke. To do this, measure off $2\frac{1}{2}$ inches from each end of the guides, and make a line. Now turn engine in the direction it is to run until cross-head has nearly completed its outward stroke and has reached the line on guide. This marks the point of exhaust closure for that end. Then turn engine around in the same direction until the cross-head reaches the line at the opposite end of the guide. The opposite exhaust valve is then set in precisely the same manner.

Roll engine on extreme of travel, and adjust the length of dash-pot rod till hook drops over block $\frac{1}{16}$ inch. Put wrist plate on opposite travel, and adjust that rod same way. Now put engine on extreme of travel, and measure off 3 inches on the stroke. Then turn engine ahead that amount, and adjust the length of reach rod till that steam valve will just trip. Turn engine on the other stroke the same amount, and adjust that reach rod till that valve just trips. Then remove the stop-motion pin, allowing governor to drop down. Roll engine over, and put eccentric at extreme travel, and adjust safety-cam till valve will not be picked up by the hook. Roll engine to opposite end until eccentric is at extreme travel, and adjust in the same manner. See that cams are not too far down, as valve may not then be picked up on starting or when on stop-motion pin. Put governor in highest position possible, and turn engine over and see that valves will not open.

Now place governor back on stop-motion pin or ring, and turn engine over. See if valves pick up.

Adjust dash-pot rods by lengthening or shortening.

DASH-POTS.

The dash-pot is to close the valve rapidly after it is tripped. A common dash-pot has inside of it a piston, and a leather flap valve in the bottom. As piston rises, air is drawn in through the leather beneath the piston, and it closes by the weight of the piston, the air being forced through a small pet cock, bringing it gently to a stop and cushioning it.

A vacuum dash-pot has 2 chambers, a vacuum and a cushion chamber, which is sufficient to close the dash-pot after the valve is released by the pressure of air outside. As piston rises, air is admitted into the cushion chamber, and, when dash-pot drops, the escape of air through the pet cock cushions the piston. If dash-pot works too slowly, open the cushion pet cock, or close it a little, if it works too quickly and pounds. With a vacuum dash-pot the vacuum is controlled by slight admission of air through a pet cock into vacuum chamber to partially destroy the vacuum. This air is expelled through a check-valve when piston drops.

The speed of the engine may be changed by changing the weights on the governor. Changing its speed of revolution, increasing size of pulley on governor makes engine run faster. The gag-pot is on the side of the governor, to steady the governor and prevent hunting. It is filled with oil, and has a piston inside with a little hole drilled through it and an adjustable plug. The more freely the oil passes through this hole, the faster the governor will move. A heavy oil will make it move slower. To make an engine give more power, the governor cuts off later in the stroke; but outside of this speed of the engine may be increased, boiler pressure may be increased, or a larger cylinder.

The clearance varies from $\frac{1}{2}$ to 3 per cent. in Corliss engines, and from 4 to 12 per cent. in high-speed engines.

BROWN ENGINE.

THE PISTON.

The piston shown in cut is of the bull and packing ring type. The two packing rings are so placed as to travel just over the cylinder counter-bores, thus avoiding the wearing of shoulders at each end of the cylinder, and give absolutely tight working under all conditions without the use of auxiliary springs or other complications.

Set screws in the piston head acting on the centre or bull ring, which in turn carries the weight of piston, allow an accurate centring of the piston at all times.

The bull-rings of the large cylinder pistons are babbitted, furnishing the very best anti-wearing property.

The piston rod is secured to the piston by a nut inside the follower, doing away with all danger of nut dropping off between piston and cylinder head,—the cause of more than one serious engine accident.

THE VALVES.

There are two steam and two exhaust valves of the flat multiported type, each set being operated by a separate eccentric, and all independently adjustable. The steam valves are placed on the side and the exhaust valves at the bottom of the cylinder, the latter furnishing a perfect drain for all water. The valves and their seats are held in bored recesses provided for them within the body of the cylinder, and are located very close to the bore to reduce clearance to the

lowest point. Free access is given to both the steam and exhaust valves through the covers at the top and back of cylinder without disturbing the releasing gear or any other parts. The valves and seats, being both separate from the cylinder and easily removed, give an opportunity for inspection and adjustment.

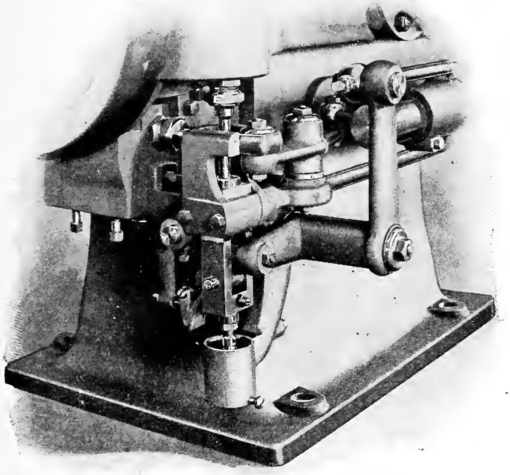


FIGURE 38.

Ample means are provided for quickly freeing the cylinder of any water which may enter, and, should there be an unusual pressure due to large amounts of water entering with the steam, relief is given by the steam valves lifting or swinging from their seats on the ball nut *I*. This action pro-

vides a much larger area for relief than would the ordinary pressure relief valves on the exhaust bonnets.

The operation of the steam valves may be clearly seen

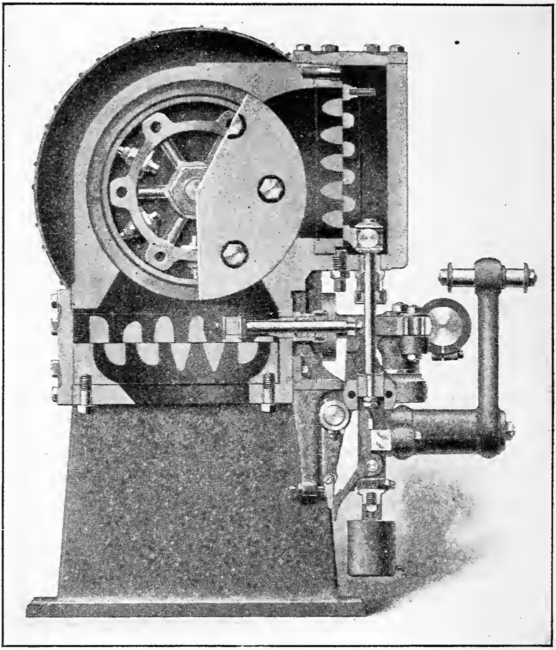


FIGURE 39.
SECTION THROUGH CYLINDER AND VALVES.

by referring to cut, which represents the position the several parts occupy at the commencement of the piston stroke.

The steel lifting block *A* connected to the lower arm of the steam lever *B*—the top of this lever being connected through the carrier arm and eccentric rod to the steam eccentric—has just engaged the latch *C*, which is journalled

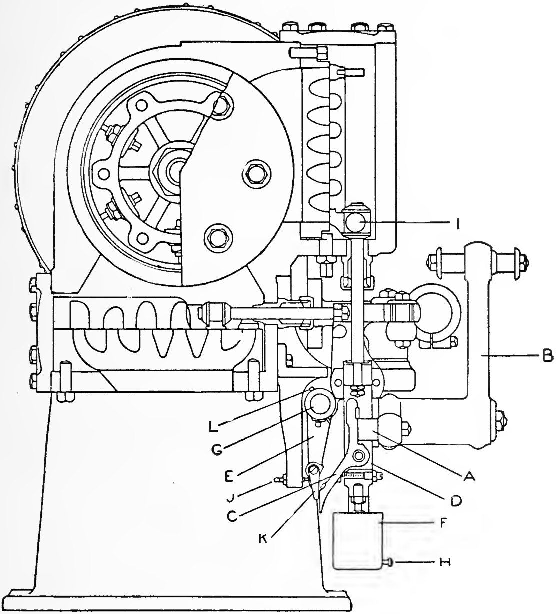


FIGURE 40.

on a pin on the steam-valve stem guide *D*. When the long arm of steam lever *B* is drawn toward the crank shaft by the eccentric, the block *A* is raised, which carries the latch and

guide up with it and causes the valve to open the ports. This upward movement continues until the tail of latch engages the trip lever *E*, which causes the latch to release the block, when the valve immediately descends, dropping by its own weight, assisted by the steam pressure on an area of valve stem and being cushioned by the dash-pot *F*, which movement closes the ports, giving a very sharp cut-off. As no springs or vacuum pots are made use of to effect this closure, the closing effort is constant at all loads, and the cut-off takes place with very little noise and without jar to the valve gearing. Any desired degree of cushion may be secured on the dash-pot by means of taper pin *H*, which may be turned to open or close vent-hole in bottom of dash-pot. The closing of the steam valves imposes no work upon the governor. The trip lever *E* is carried by the trip shaft *G*, which is connected to and actuated by the governor.

The exhaust valve mechanism is operated in an entirely new manner.

The exhaust sliding bar *A*, which is connected through the carrier arm and eccentric rod to exhaust eccentric, is connected by link *B* and exhaust lever *C* to the exhaust-valve stem guide *D*, which is connected by the valve stem *E* to the exhaust valve. By this arrangement the movement of the valve is concentrated at the points of opening and closing, giving a long pause between, which results in a free exhaust and absence of back pressure, both of the greatest consequence in the case of the low-pressure cylinder of a compound engine.

Separate eccentrics being used for steam and exhaust valves, allow separate adjustment for each, and give the wide range of cut-off and compression desirable for compound engines. Valves have short motions, and in conse-

quence the engines may be run at high speed, making them suitable for electric work, and yet have the economy due to the drop cut-off and four independent valves. Valves are closed positively in case the stem is packed too tight or for any reason they do not act properly.

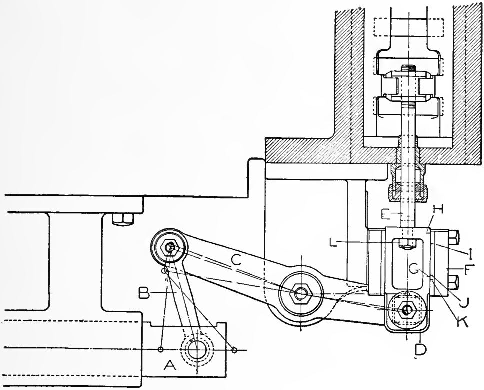


FIGURE 41.
EXHAUST VALVE MECHANISM.

SETTING THE VALVES OF THE NEW BROWN ENGINE.

When about to set the valves of the "Brown," the first requisite is the proper adjustment of the four valve stems to secure the necessary lap on each valve.

Beginning with the steam valves, remove guide box *A* (Figs. 40–41), and on valve-gear bracket a scratch mark *B* prick-punched at each end will be found. Now disconnect dash-pot connections from steam-valve stem guide *D*, and allow valve to drop as far as it will go, and then adjust by

turning valve stem in or out of valve nut until the distance between scratch mark *B* on valve-gear bracket and bottom of brass drip cup *C* is the exact width of steel gauge, or $\frac{7}{8}$ inch. Then make stem fast to guide by means of nuts at *E*.

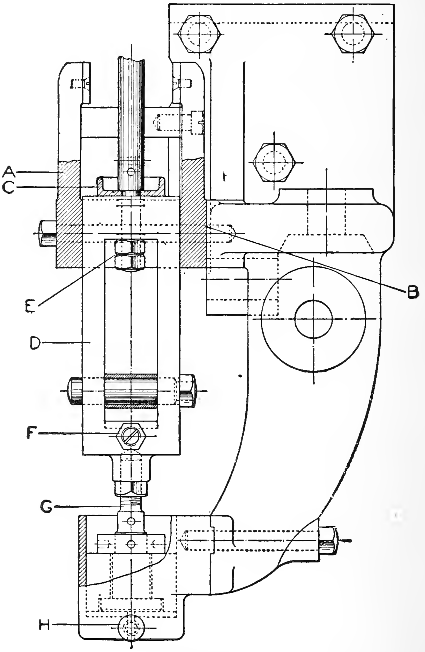


FIGURE 42.

The dash-pot stem *G* should then be adjusted until the top prick-punched scratch mark on guide *D* just shows above the top of guide box. Tighten nut on dash-pot stem. Make

these adjustments on both steam valves. Now turn the full side of steam eccentric on the dead centre farthest from the cylinder, having first seen that the dash-pot on crank-end steam valve is properly seated. When the eccentric occupies the dead centre, the lifting block A on crank end should then have just engaged the latch, with perhaps $\frac{1}{32}$ inch clearance. If this is not the case, the eccentric rod should be adjusted until this clearance is obtained. When the eccentric occupies the dead centre nearest the cylinder, see that the foregoing conditions are fulfilled at the head, or end, of the cylinder farthest from the crank shaft. If such is not the case, adjustment must be made by the right and left rod connecting the two steam levers until proper clearance is obtained on the head end.

Now have the eccentric turned around on the shaft, and see that both valves are alternately raised an equal distance, which will be the case if the adjustments have been properly made.

Place the crank and the full side of the eccentric on the dead centre nearest the cylinder. The lifting block should have now just engaged the latch on head end. Have the eccentric turned around on the shaft in the direction in which the engine is to run until the valve opens the ports the amount of the lead, which should not exceed $\frac{1}{64}$ inch, unless it is positively known that the engine will run better with more lead. Have the eccentric fixed to the shaft at this point. The amount of lead may be accurately determined by removing the upper head of the valve chests and measuring the lead by means of pieces of thin steel $\frac{1}{64}$ inch thick. The end of the steel strip is to be placed against the valve seat while the eccentric is being slowly turned around on the shaft. As soon as the strip enters the port, the valve will have opened $\frac{1}{64}$ inch.

Have the crank turned, in the direction it is to run, to the opposite dead centre, or crank end.

The opposite steam valve should now have opened the port the amount of the lead, which it will do, provided the work of equalizing the movements of the valves has been properly done. If the lead is found to be correct, the eccentric must then be permanently fixed in the position in which it will now be found on the shaft.

The movement of the exhaust valves is now to be equalized in the same manner as for the steam valves. Marks will be found on the exhaust-valve stem guide *D* and guide box *F* showing position of valves, or, should the marks have become obliterated, the valves may be seen by removing the valve chest bonnets, and by the aid of pieces of thin steel their exact location may be determined, the same as with the steam valves.

To determine the proper length of exhaust-valve stem, draw the valve forward, until it strikes. Screw the valve stem into the valve nut until marks *H* and *I* come together, then make nut fast at *L*. The lines *J–K* show the lap of valve. *G* and *J*, when together, show the opening line.

To set the exhaust valves, mark the guides on the frame at each end, varying from $2\frac{1}{2}$ inches for the small engines to 3 inches or $3\frac{1}{2}$ inches for the larger ones from the full stroke of the cross-head. Then have the crank turned in the direction the engine is to run until the cross-head reaches one of these marks.

Assume that the exhaust eccentric is on the dead centre nearest the cylinder and that the cross-head has reached the line on the guides nearest the cylinder. The exhaust eccentric is now to be turned around on the shaft in the direction the engine is to run until the exhaust valve on head

end just closes the port, or until lines *G* and *J* come together. Fix the exhaust eccentric to the shaft at this point. Then have the crank turned in the direction it is to run until the cross-head reaches the line at the opposite end of the guides, when the exhaust valve at that end of the cylinder should have just closed the port also.

If it does, the compression will then commence when the piston reaches a point from the end of the stroke corresponding to the distance marked on frame guides.

The proper amount of compression and lead will have to be finally determined by an indicator after the engine has been started and run under working conditions. This we would recommend doing in every case.

If an engine is to be run condensing, it will require more compression than an engine running non-condensing.

After both sets of valves have been properly adjusted, attention should be given the governor.

Loosen the governor springs until the weights can be readily moved from one position to the other by means of the central stem. Now press the stem in until the weights are in their outer position, and block them. Loosen set screw in governor connection lever on trip shaft, and move the trip lever *E* nearest governor, which is permanently fastened to the trip shaft, either toward or away from the latch, as the case may require, until the crank-end steam valve upon being raised will cut off when the second prick-punched scratch mark, on guide *D*, appears at the top of guide box. Then tighten set screw in governor lever on trip shaft. That is, with the governor weights in their outer position, the steam valve is only allowed to lift enough to just uncover the lap. The lap is the distance between the first and second scratch marks.

Place the small handle on the front of governor in a vertical position and pull stem out until it is stopped by the handle, which will bring the governor weights to their inner position. The steam valve, now being raised, should not be cut off until the third prick-punched scratch mark shows at top of guide box, or $\frac{1}{16}$ inch less than the full throw of the short horizontal arm of steam lever *B*. The movements of the two steam valves may now be equalized by means of the taper pin *L*, in trip lever of head-end steam valve. This acts as a taper key. By loosening set screw and driving pin in, the cut-off is shortened. By driving out, the cut-off is lengthened.

Setting the safety-stop. With the small safety-stop handle in a horizontal position and the central stem pulled out as far as it will go, the governor balls are allowed to reach an extreme point beyond their inner governing position, which imparts to the central stem an extra $\frac{7}{32}$ inch motion beyond its working limit. Block the governor in this position. Now screw *J* in until lower end of pawl *K* strikes tail of latch *C*, and steel on upper end of latch is just thrown out of engagement with lifting block *A*. Make check nut tight on screw *J*.

This adjustment being made on both ends of the cylinder, each valve should be raised two or three times to see that clearance has been properly given between steel on latch and lifting block, so that latch cannot hook on at this point.

Thus, should the governor belt break or by any other cause the governor balls be allowed to reach their extreme inner position, the steam valves remain seated, thus cutting off any further supply of steam to the cylinder. This is a most efficient and positive device, and would be the means of saving an engine from destruction, where a governor without some such device would be absolutely powerless

The safety-stop handle should always be in a horizontal position while engine is running, being moved to the vertical position just previous to shutting down.

FLY-WHEEL GOVERNOR.

How do you set the valve of an engine having a fly-wheel governor?

If governor is not keyed to the shaft, find its proper position by putting the engine on the head-end centre, having the slot in eccentric come at right angle to the crank. Move weights in or out, and see if valve moves. If it does, move the wheel back and forth till you find the place where you can move the weights in and out without moving the valve. Fasten the valve there, and give the engine $\frac{1}{32}$ lead on the head end by adjusting the valve stem or eccentric rod. Put on opposite centre, and note lead, if more, should not be changed. It should not be less on the crank end than the head end. Block out governor to see if cut-off is equal.

What is a throttle governor?

A throttle governor is placed on the steam pipe, and governs engine by checking or throttling the pressure of steam as it enters the steam chest; but the point of cut-off does not change with a throttle governor, although the steam pressure in cylinder changes with the load.

What is an automatic governor?

An automatic governor does not change the steam pressure entering the cylinder, but changes the point of cut-off with every change of load.

What is the rule for finding the size of governor pulley, having given revolutions of engine, size of pulley on shaft, and revolutions of governor?

Rule.—Multiply the diameter of governor pulley by the revolutions of engine, and divide the product by the revolutions of governor.

Example.—It is required to change the speed of an engine now running 85 revolutions to 132 revolutions. The governor runs 110 revolutions. Pulley on crank shaft 10 inches diameter. What size pulley must be used on governor shaft?

```
                 132  = revolutions of crank shaft.
                  10 = diameter pulley on crank shaft.
                ----
                1320
revolutions of governor = 110)1320(12 = inches diameter
                              110          pulley.
                              ---
                               220
                               220
                               ---
```

Example.—An engine having a governor running 110 revolutions, driven by a 12-inch pulley on governor shaft, what size pulley must be placed on crank shaft to make engine run 132 revolutions per minute?

```
                 110 = revolutions of governor.
                  12 = diameter of governor pulley.
                 ----
                  220
                 110
                 ----
                 1320
revolutions of engine = 132)1320(10 = inches diameter of
                            132        pulley on crank shaft.
                            ---
```

LUBRICATOR.

How is the piston lubricated?

The piston in the cylinder is lubricated through a sight-feed lubricator attached to the steam pipe. In filling the lubricator, all valves are closed. Open drip at bottom to let the water out. Removing filling plug at top of cup, the oil will show in the glass. The lubricator has connection with the steam pipe about two feet above the cup: the feed is opposite the cup, the steam pressure being alike at each opening. To overcome this, greater pressure is obtained by the weight of water which is condensed in the longest upright pipe. The weight of this column of water gives the additional moving force in excess of the steam pressure; and, to start the oil and lubricator feeding, this pipe must be full of water, or lubricator will not feed.

Lubricators sometimes have but one connection with the steam pipe. In this case the water displaces a certain amount of oil which flows into the steam pipe.

The feed, or drops, per minute is regulated by a small valve.

The average feed is one or two drops per minute.

CRANK PIN.

To determine whether a crank pin is in line with the centre of the cylinder or not, put on the connecting rod, and key the boxes up snug on the pin. Then disconnect the rod from the wrist of the cross-head, and move the crank round; and, if the rod maintains a central line in whatever position the crank may be placed, the crank pin is in line with the centre of the cylinder. This test will also serve

to prove the correctness of the boring of the pin boxes. If they are not bored exactly at right angles to the centre line of the rod, troubles similar to those caused by an untrue pin will ensue. Another oversight not generally thought of, and which causes much trouble with the crank pin, is that in planing off the stub end of the connecting rod more is planed off on one side than the other. As a result, every time the rod changes its position, the boxes will pinch on the crank pin, and cause undue heating.

CHAPTER VI.

PUMPS.

What is a power pump?

A power pump is one driven by a belt. It may be stopped by running belt off on loose pulley. A by-pass valve on suction side controls the amount of the water pumped. For hot water, pump should always be below the source of supply, as a pump will not lift hot water.

What is a single pump with high-pressure steam end for boiler feed?

A single pump with high-pressure steam end has one steam cylinder and one water cylinder. The water end is double acting. That is, it is drafting water on one side of the piston while it is discharging on the other side. Consequently, it is both drafting and discharging at the same time, no matter which way it is travelling. A double-acting pump has one or more suction valves and one or more discharge valves at each end of the cylinder. Water enters the pump through the suction pipe into the suction chamber, through the suction valves into the cylinder, as the piston moves away; and, when the piston reverses its motion, the suction valves, through which the water enters, are closed, and the water is forced up through the discharge valves into the air chamber from which the discharge pipe is taken. The suction pipe is always the larger pipe, and is usually at the bottom of the cylinder.

What is a double pump?

A double pump with high-pressure steam end has two steam cylinders and two pump cylinders side by side, and

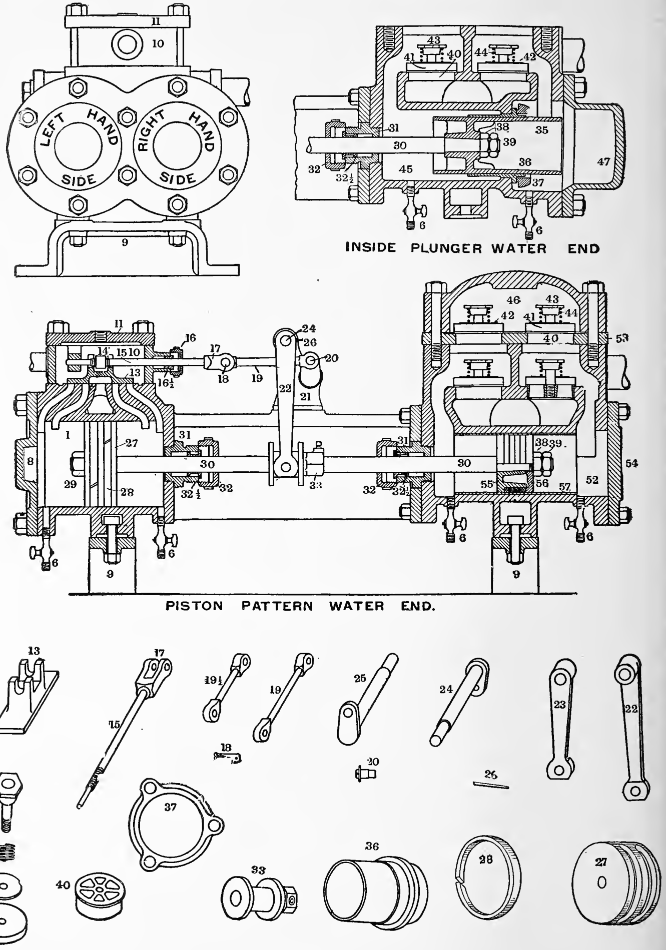

LEFT HAND SIDE
RIGHT HAND SIDE
INSIDE PLUNGER WATER END
PISTON PATTERN WATER END.

FIGURE 43.

either cast together or connected together, so as to operate as one pump. It has one or more suction valves and one or more discharge valves for each end of each pump cylinder.

What is a single-acting pump?

Some power pumps are single acting on pump end; that is, they have valves at only one end of the cylinder. Con-

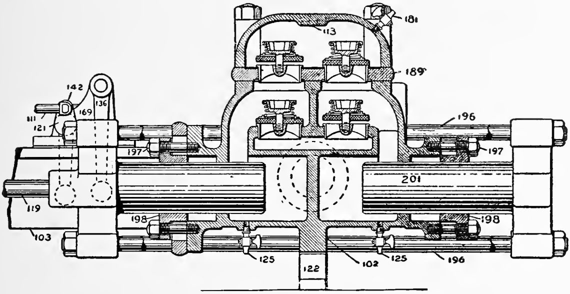


FIGURE 44.
OUTSIDE PACKED DOUBLE PLUNGER PATTERN.

sequently, can only draft water when the piston or plunger is being moved away from the end of the cylinder where the suction valves are, and discharges the water on the return stroke. Some steam pumps have a partition in the middle of the pump cylinder and single-acting plungers running into and out of each end of the cylinder; but, as one plunger is always travelling toward the valves when the other is travelling away, the pump end, as a whole, is consequently double acting.

SINGLE STEAM PUMP IN DETAIL.

Describe the difference between a piston and a plunger pump.

In a piston pump the piston fills the whole diameter of the cylinder, while in a plunger pump the plunger does not fill the whole diameter of the cylinder, and only pumps such water as is displaced by the plunger.

Plunger pumps of the so-called inside plunger or plunger and ring pattern, where the plunger is located within the

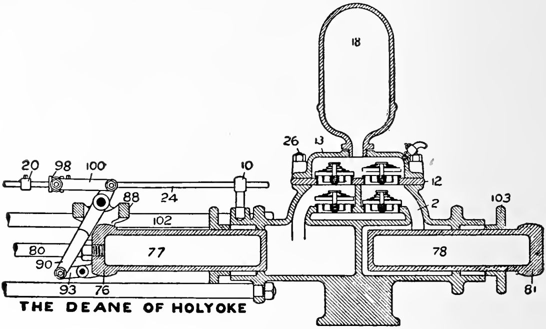


FIGURE 45.
DOUBLE PLUNGER PATTERN.

cylinder, and travels forward and backward in the partition between the two ends of the cylinder, are not packed, the plunger sliding in a long sleeve, or lining.

Outside plunger pumps—that is, those where the plunger moves in and out of the cylinder from the outside—are packed in the stuffing boxes through which they travel.

How high will a pump lift water?

When liquids are cold, a pump of design for good suction efficiency will lift water 20 to 25 feet vertical, according to the speed it runs. Horizontal run of piping and turns, or elbows, on suction side will reduce this in proportion to the friction loss which they cause.

What enables a pump to lift water from a well?

By the action of the pump making a partial vacuum in the suction pipe, the atmospheric pressure forces the water up to the pump.

How high will a pump lift water?

The highest theoretical lift possible is 34 feet.

What enables a pump to force water into a boiler?

To force water into a boiler, the steam piston must be of larger area than the water piston. The area of the steam piston in proportion to the water piston varies according to the boiler pressure against which the pump delivers. The size and length of discharge pipe and the number of elbows, or bends, in the same also effect this. This ratio runs from $2\frac{1}{2}$ to 1 for high-steam pressure up to as high as 13 to 1 for low-steam pressure, such as 5 to 10 pounds.

Can a pump lift hot water?

A pump cannot lift hot water. Therefore, it must be placed below the water supply.

Can you tell when a pump is not pumping?

Pump will run fast. You get an unsteady stream of water from the pet cock on air chamber, if water is too hot. In this case, water must be cooled. Open city supply.

Give some reason why a pump will fail to work.

There are many things to prevent a pump from not pumping. Pump might be air-bound, too much air in air chamber, or steam-bound, which is caused by the water being too hot. Pipe might leak, strainer may be clogged, suction valves have dirt under them or caught up, springs broken, valves may be worn out. A priming pipe enters suction pipe, if there is a foot valve on the suction pipe. If not, the priming pipe is connected to pump above the suction pipe and below the discharge valve. If suction pipe is too small for the

pump, it will not deliver water enough to the pump; and pump will speed up and pump less water when running fast or if a suction is too long.

Of what are the pump valves made?

The pump valves are made of vulcanized rubber or brass for hot water and medium or soft rubber for cold water.

Of what use is the air chamber?

The air chamber on the pump is to cushion the water and give it a steady flow. Air chambers are not necessary on a duplex pump, as one side is always pumping. To start up a pump, open all drips, open suction and discharge valves, also steam exhaust, and turn on steam. When water is out of the steam cylinder, shut the drips.

What style of packing is usually found on a pump?

The steam piston does not need packing which is packed with a special metal-ring packing. The pump piston is usually packed with square canvas and rubber packing or braided hemp of special brand, as may be required to correspond to temperature of liquid being handled. To pack the piston on the water end, take off the follower plate, and remove old packing, replace new packing, breaking joints with the packing. Replace follower plate with head and nuts. When piston is packed properly, pump will run steady and pump a good amount of water.

Pumps do not usually come with stuffing boxes packed, and should be packed with make and grade of packing best suited to the service on which the pump is to work.

SETTING PUMP VALVES.

In general how would you set the valve of a duplex pump?

First we must find the middle position. Move the piston till it strikes the head, and make a mark on the piston rod opposite stuffing box. Move piston till it strikes the opposite head, and mark on the rod. Now get the centre between the two marks on rod, move piston back till middle mark is in line of the gland. The rocker arm of each side should be in mid-stroke. Valves should be set to just cover the ports, then the lost motion between the valves and nut on valve rod should be exactly equal. The steam valve of each cylinder is controlled by the action of the opposite piston.

Describe the operation of a Deane pump.

In the Deane single pump the piston in its travel operates tappets secured to the valve stem, operating an auxiliary valve which admits steam to one end and exhaust steam from the other end of a supplemental piston. This piston moves the main valve by direct pressure of steam on alternate end, which admits steam to the main piston. The length of stroke can be increased by putting tappets farther apart. The valve stem is connected to auxiliary valve. In moving this supplemental piston, it shuts off its own exhaust port, confining steam to cushion it and prevents it striking the head. It is prevented from rotating by a bolt through the side entering the slot in piston. If, however, the supplemental piston fails accidentally to be moved, or to be moved with sufficient promptness by steam, the lug on the valve rod engages with it, and compels its motion by power derived from the main piston.

How many ports has the steam cylinder of a Deane pump?

The Deane pump has seven ports, three for the main valve and four for the auxiliary valve.

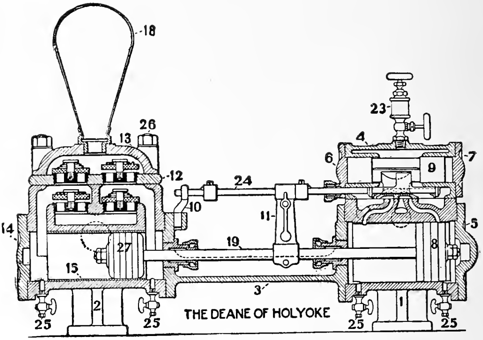


FIGURE 46.
TAPPET MOTION PATTERN.

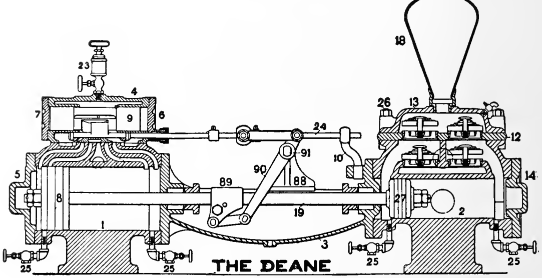


FIGURE 47.
LEVER MOTION PATTERN.

DIRECTIONS FOR SETTING UP AND OPERATING PUMPS.

In setting up a pump, the first requisite is to provide a full and steady supply of water or other fluid. To accomplish this, observe carefully the following points:—

The suction pipe in all cases to be of sufficient size to supply water cylinder. If pipe is long, it must be larger, as the friction due to unusual length will partly overcome the head due to the vacuum, and prevent a full supply. Make pipe, therefore, as short as possible, but make as few bends, and always make these as easy (*i.e.*, long radius) as possible.

In laying suction pipe, a uniform grade should be maintained, thereby avoiding air pockets or summits. Grade the suction pipe toward the supply with a drop of not less than six inches in each 100 feet. It will be found economical to have grade given by a civil engineer.

The suction pipe and its connections must be tight, as a very small leak will supply the pump with air to its full capacity, so that little or no water will be obtained, according to the size of the leak. Before covering the suction pipe, it is recommended that it be tested with a pressure of not less than twenty-five nor more than fifty pounds per square inch, to discover any leaks.

Wrought-iron pipe may be used for suction pipe of small sizes, but cast-iron flanged pipe is recommended for all sizes in which it can be obtained. When bell and spigot pipe is used, it should be laid with the direction of the current from the bell end towards the spigot end.

All valves in suction and discharge pipes should be gate valves.

A suction air chamber is an advantage on long or high

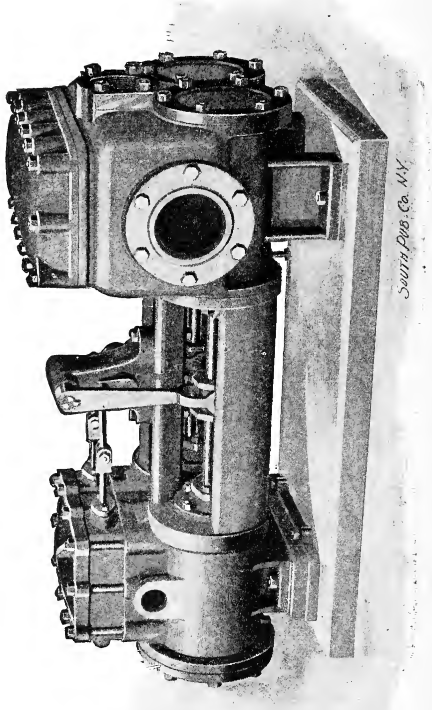


Figure 48.
Duplex Pump.

suctions, and is particularly recommended for single pumps, on all fire pumps, and any pumps which are to run at high speed, especially for pumps of short stroke.

A foot valve, under these conditions, insures a quick starting of the pump by maintaining the pipe full of water and free from air. When a foot valve is used, see that the area of its valve seat opening is not less than the area of the pipe.

A strainer is always desirable, but not necessary when water is clear and free from foreign matter that will clog the valves and passages of the pump. The area of the strainer openings should be at least four times the area of the pipe, to equalize the friction of water through the small openings, and because some of them are liable to become clogged. When strainers are used, they must be frequently inspected, and cleaned.

Extreme caution must be exercised while pipe is being laid and pump connected, to prevent foreign matter, such as sticks, waste, and rubbish, from entering the pipe. Chips from threading pipe, sand, etc., will quickly cut the cylinder, piston, and valves of a pump, doing more damage than years of proper use, or perhaps entirely disabling it.

A priming pipe connected to a supply above the pump or under pressure is a convenience for quick starting, and a necessity for a fire pump and most large pumps of all classes.

Hot water cannot be raised to any considerable height by suction. Thick liquids and hot water should always flow to the pump by gravitation.

The steam, exhaust, suction, and discharge pipes should all be as straight and as free from turns as possible.

In connecting the steam pipe, proper allowance should be made for expansion. A gate throttle valve should be

placed in the steam pipe close to the pump. Means should be provided for draining this pipe before starting the pump.

A heater may be placed in the exhaust pipe to advantage.

To prevent freezing, drain the pump by opening all cocks and plugs provided for the purpose. In piping from these drips, valves should be placed close to the pump cylinders. The steam and water cylinder drips should never be connected into the same pipe unless a check-valve is placed so as to close towards the water cylinder to keep it free from steam.

Foundations suitable for the pump should always be provided.

All pipes should be properly supported so as to relieve the pump flanges from undue strains.

Keep the steam cylinder well oiled, especially just before stopping.

Keep the stuffing boxes well and evenly filled with a good quality of packing. Don't screw them too tight.

Let the steam end alone, if the pump begins to run badly, until fully satisfied that there is no obstruction in the water cylinder, water valves, or pipes.

The pump should be located, if possible, in a light, dry, warm, and clean place, and have good care. Do not overlook the importance of this last suggestion.

Do not pull the pump apart to see what is inside, as long as it does its work well.

THE DEANE.

Duplex Steam Pump in Detail.

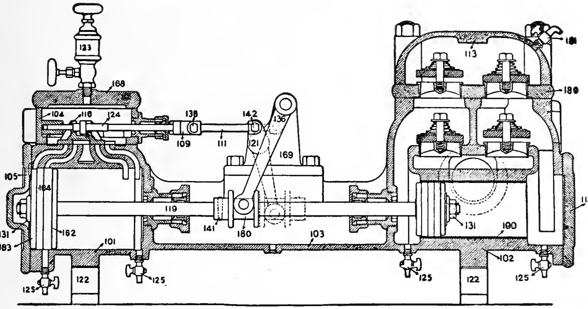


Figure 49.

Piston Pattern.

LIST OF PARTS.

1. Steam Cylinder.
2. Water Cylinder.
3. Yoke.
4. Valve Chest.
5. Steam Cylinder Head.
6. Inside Valve Chest Head.
7. Outside Valve Chest Head.
8. Steam Piston.
9. Valve Piston.
10. Guide.
11. Tappet Arm, with bolts and nuts.
12. Water Valve Plate.
13. Water Cap.
14. Water Cylinder Head.
15. Water Cylinder Lining.
16. Main Valve.
17. Auxiliary Valve.
18. Air Chamber.
19. Piston Rod.
20. Tappet.
21. Tappet Key.
22. Tappet Set Screw.
23. Lubricator.
24. Valve Rod.

25-25-25-25. Drip Plugs or Cocks.

26. Eye Bolt and Nut.
27. Water Piston, complete with packing. (See Nos. 44 to 47.)
28. Bushing, } for Piston Rod Stuffing Box.
29. Gland, } for Piston Rod Stuffing Box.
30. Cap, } for Piston Rod Stuffing Box.
31. Nut, } for Piston Rod.
32. Flange Nut, } for Piston Rod.
33. Check Nut, } for Piston Rod.
34. Cap, } for Valve Rod Stuffing Box.
35. Gland, } for Valve Rod Stuffing Box.
36. Water Piston, head only, } for Leather Cup Piston.
37. First Follower, } for Leather Cup Piston.
38. Second Follower, } for Leather Cup Piston.
39. Leather Cup Packing.
44. Water Piston, hd. only, } for Patent Fibr's Ring Packing. See No. 27.
45. Follower, } for Patent Fibr's Ring Packing. See No. 27.
46. Inside Ring, etc., } for Patent Fibr's Ring Packing. See No. 27.
47. Fibrous Packing, } for Patent Fibr's Ring Packing. See No. 27.
48. Seat, } for Rubber Water Valve.
49. Stem, } for Rubber Water Valve.
50. Spring, } for Rubber Water Valve.
52. Cover, } for Rubber Water Valve.
51. Rubber Water Valve.
75. Tappet Arm, } for Double Plunger Pumps.
76. Inside Cross-head, } for Double Plunger Pumps.
77. Inside Plunger, } for Double Plunger Pumps.
78. Outside Plunger, } for Double Plunger Pumps.
79. Side Rods, } for Double Plunger Pumps.
80. Piston Rod, } for Double Plunger Pumps.
81. Outside Cross Head, } for Double Plunger Pumps.
84. Stem, } for Metal Disc Valve.
85. Spring, } for Metal Disc Valve.
87. Seat, } for Metal Disc Valve.
86. Metal Disc Valve.
88. Bearing Stand.
89. Piston Rod Arm.
90. Lever.
91. Fulcrum Pin.
92. Tappet Block Nut.
93. Piston Rod Link.
94. Link Pin.
95. Piston Rod Arm Bolt.
96. Piston Rod Arm Pin.
97. Lever Pin.
98. Tappet Block.
99. Gland for Stud Stuffing Box.
100. Valve Rod Links.
101. Link Stud, Washer and Nut.
102. Yoke Rods.
103. Plunger Glands.

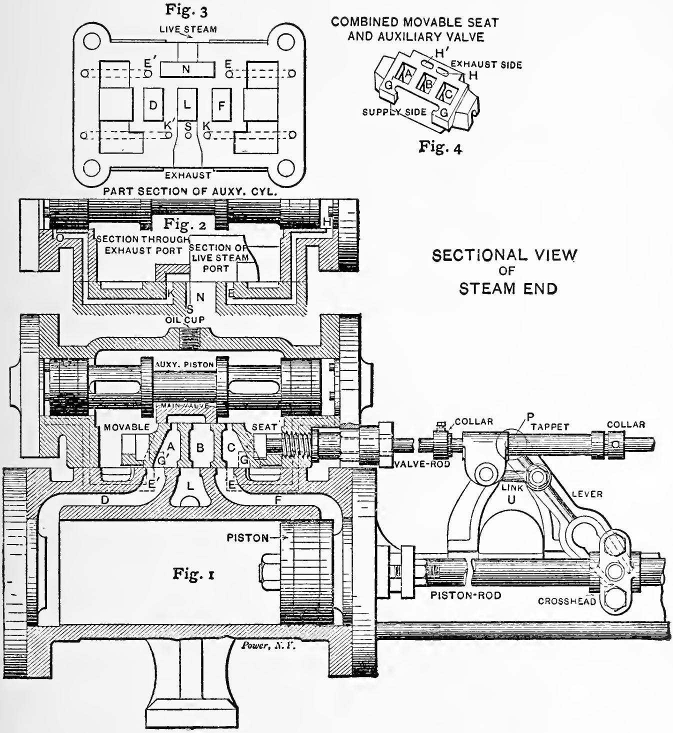


FIGURE 50.
SECTION OF STEAM END OF A BLAKE SINGLE PUMP

In an ordinary engine the reciprocating motion of the piston is converted into a rotating movement of the fly-wheel by means of a crank. An eccentric secured to the shaft drives the valve. With the ordinary type of pump this means cannot be employed, as there is no rotary motion which can be used to actuate the valve. A difficulty arises in this connection from the fact that, when the valve is central, steam is cut off from the cylinder, and there is no momentum stored in a fly-wheel to force the valve in either direction to open the port. This difficulty exists in all pumps, and the means adopted to overcome it constitute the distinctive features of the Blake pump. In pumps, as in engines, the valve motion is derived from the stroke of the piston; and it is our purpose to describe the means of derivation employed, the methods adopted to obviate the "dead-centre" difficulty, and the processes of setting the valve gear so as to secure the best results.

Figs. 1, 2, 3, and 4 represent the steam end of the Blake pump. This is the arrangement of the boiler feed and pressure pumps. First, we will consider the valve movement, without any regard to the gear by which it is accomplished.

The main valve, which controls the admission and exhaust of steam from the main cylinder, is carried by the auxiliary piston, and moves on the back of the movable seat. This movable seat is shown in Fig. 4 in perspective, and the passages *A*, *B*, *C*, serve as steam ports to the main cylinder; while the lugs *GG′* control the admission of steam to the auxiliary cylinder and the holes *HH′* control the exhaust from that cylinder.

With the valves in the position shown, the course of the steam is through live-steam passage N, through the port *C* to the right-hand end of the main cylinder, thus forcing the

piston over to the left. Now, when the piston nearly reaches the left end of the cylinder, the movable seat, by a means described later, is shifted over to the left, so that the lug G covers the port E, while the lug G' moves off from the port E', thus admitting steam behind the auxiliary piston, at the left-hand side. At the same time the exhaust port K of the auxiliary cylinder is put into communication with the hole S which leads to the exhaust. The auxiliary piston is therefore forced over to the right, and uncovers the port A to live steam. Near the right-hand end of the stroke the operation is reversed. That is, the movable seat, which is then at the left, is moved over to the right, assuming the position shown in Fig. 1. The lug G then uncovers the port E, while E' is covered by G'. This admits live steam to the right of the auxiliary piston. At the same time the hole H' in the auxiliary valve or movable seat places K' and S in communication, thus exhausting the steam from the left of the auxiliary piston. This drives the auxiliary piston over to the left, until it assumes the position shown in Fig. 1.

The auxiliary piston is cushioned on steam, because the exhaust port is not out at the end of the auxiliary cylinder, and consequently there is steam imprisoned when the piston covers the exhaust, as shown at the left in Fig. 2. The main piston is cushioned on live steam, because the valve has lead; that is, the operation of admitting steam is performed before the piston reaches the end of its stroke.

It will be seen that, if means are provided to shift the movable seat from one end of its travel to the other, the rest of the operation is automatic. Fig. 1 shows the valve gear provided for this operation. The piston rod is provided with a cross-head, the latter having a pin as shown. The frame of the pump is built with an upright piece, U, to which is pivoted

at P a lever whose lower end is slotted and engages with the cross-head. The valve rod, which is secured to the movable seat, is provided with two collars, as shown. These collars are made of split nuts which work on a thread cut on the valve rod for a short distance on each side of their ordinary position. Between these two collars is a tappet, which is free to slide on the valve rod. The link shown connects the tappet with the lever. When the piston rod moves, the lever rotates about P, carrying the tappet with it; and, when the tappet strikes either collar, it moves the movable seat in the direction in which the tappet is moving. By placing the collars so that the tappet strikes them before the piston reaches the end of its stroke, the movable seat will be shifted in the required manner.

No valve adjustment is required to be made inside the steam chest, and the only adjustment which can be performed is that of altering the distance between the collars, thus changing the travel of the valve. This is done by loosening the set screws in the collars and rotating the latter until they come to the required point. Changing the distance between the collars alters the length of the stroke. This is easily seen, because the action of the tappet in striking the collars is what admits and exhausts the steam; and, if the distance which the tappet has to travel is varied, the time at which the valve is actuated is varied, and the stroke varies as well.

The adjustment of these collars is very simple, and can be performed while the pump is running. In adjusting them, it is desirable to make the stroke as long as possible and secure enough cushioning, for the shorter the stroke the greater the amount of clearance, and the steam required to fill the clearance is wasted on every stroke.

If the collars on the valve rod are not set at equal distances from the centre line of the lever when the latter is vertical, the movable seat will be reversed sooner on one stroke than on the other, and consequently the piston will travel further in one direction than in the other.

THE MASON PUMP GOVERNOR.

The Mason pump governor is to the direct-acting steam pump what the ordinary ball governor is to the steam engine. It attaches directly to the piston rod of the pump, and operates a balance valve placed in the steam pipe, thereby exactly weighing the amount of steam to the needs of the pump, and economizing the same. By using the Mason governor, you can instantly set or change your pump to any required speed, which will be maintained in spite of variation in load or steam pressure. As all the working parts of the governor are immersed in oil, the wear is reduced to a minimum. It is largely used on vacuum pumps and all classes of pumps requiring a uniform stroke.

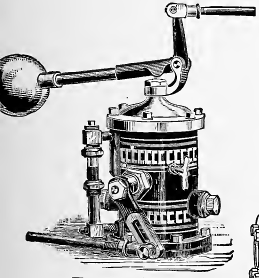


FIGURE 51.

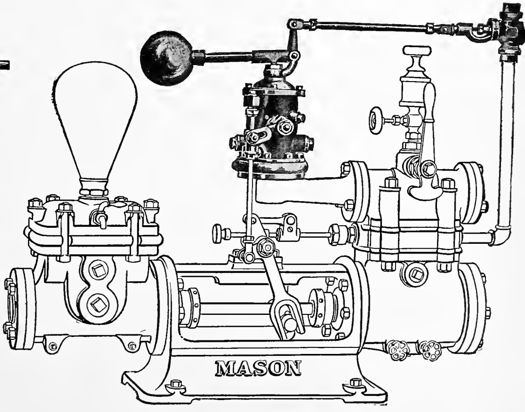


FIGURE 52.

CHAPTER VII.

CONDENSERS.

What is a condenser?

It is a closed vessel in which steam is brought in contact with water or cooled tubes, and thereby condenses or reduces the steam to water.

What are the types of condensers?

Surface and jet.

Describe the surface condenser.

The surface condenser consists of a shell nearly full of small tubes, ranging from $\frac{5}{8}$ to $\frac{3}{4}$ inch in diameter, and which are made fast to tube plate on each end. Through these tubes water is circulated. Between the inner and outer heads suitable partitions are made to keep the flow moving without disturbance of other currents of water. Steam is admitted to the top, and, coming in contact with the cooled tubes, condenses or is reduced to water, and falls to the lower port of condenser. From there it is pumped to hot well. With this type of condenser are provided a circulating pump, which circulates or forces the condensing water through the tubes, and an air pump, which frees the condenser of water condensed from the steam. This discharge, as stated before, goes to the hot well. The circulating pump's discharge is carried to a cooling tank, or, if the plant is located by a river or stream where clear water is available, it takes its suction and discharges to this source. In this type the steam and water never come in contact.

What particular advantage has this type of condenser?

It can be used where the fresh-water supply is poor or limited or where salt water is available for circulation.

Why are tubes of small diameter used?

To obtain as much cooling surface as possible within the condenser shell. These tubes are made quite thin, usually about $\frac{3}{64}$ of an inch, so that they will not hold the heat given out by the steam.

How are condenser tubes made tight in the plate?

By wood or sometimes paper ferrules, which fit the tubes and are driven into the tube plate, or by glands tapped into the tube plates with suitable packing to press against the tube, making a tight joint.

What type of pump is almost always used with a jet condenser?

A single-acting, vertical bucket air pump.

Describe the action of a bucket pump.

The bucket air pump is a single-acting pump. In fact, a piston with valves fitted to it which closes on the up stroke and opens on the down, lifting a quantity of water equal to its capacity at each stroke of the engine. A dependent air pump is driven by the engine itself, starts and stops with the engine.

The dependent pump is usually driven by a connecting rod from the crank pin, connected to the long arm of the lever, the short arm of lever operating the pump. A bucket pump has valves in the piston or bucket. The piston is attached to a large hollow piston rod called a trunk, and has the wrist pin at the bottom of this hollow piston or trunk. This trunk acts as a guide, and works through a stuffing box. The water passes from the bottom of the condenser, through a channel way, to the air pump, and, as the bucket descends,

the water passes through the valves in the bucket, and, when the bucket rises, this water is forced through a set of valves in the delivery plate above. The valves in the bucket are called the bucket valves. The valves in delivery plate are called the discharge valves. To get at the valves and bucket, take off the hand-hole cover above delivery plate, then the bucket valves and bucket can be seen. The air-pump lining is made of brass. Bucket is kept tight by square hemp packing, or by wood packing, of blocks made of maple, about 4 inches wide and $\frac{1}{2}$ inch thick, like staves of a barrel. Between the bucket and the wood, rings of rubber hose hold the packing out against sides of the cylinder. The trunk is packed like an ordinary piston rod.

Describe a jet condenser.

The jet condenser consists of a body casting, on the top of which the exhaust from the engine enters, and in its passage through comes directly in contact with a sheet of water from the injection main; then it condenses and falls to the base of the condenser, and is removed by the air pump. The spray or sheet of injection water is regulated by a hand wheel on top of condenser, and care must be taken to regulate the speed of air pump to handle this injection water, the condensed steam, and the air brought in with the injection water.

Could you use a surface condenser, in case of emergency, for a jet condenser?

To enable a surface condenser to be used as a jet condenser in case of accident to the circulating pump, a pipe leads from the injection cock of the circulating supply pump into the bottom of the exhaust pipe or column, where it enters the condenser. This pipe is supplied with a spray or rose nozzle, which divides up the injection water and causes it to condense the steam as it enters the condenser.

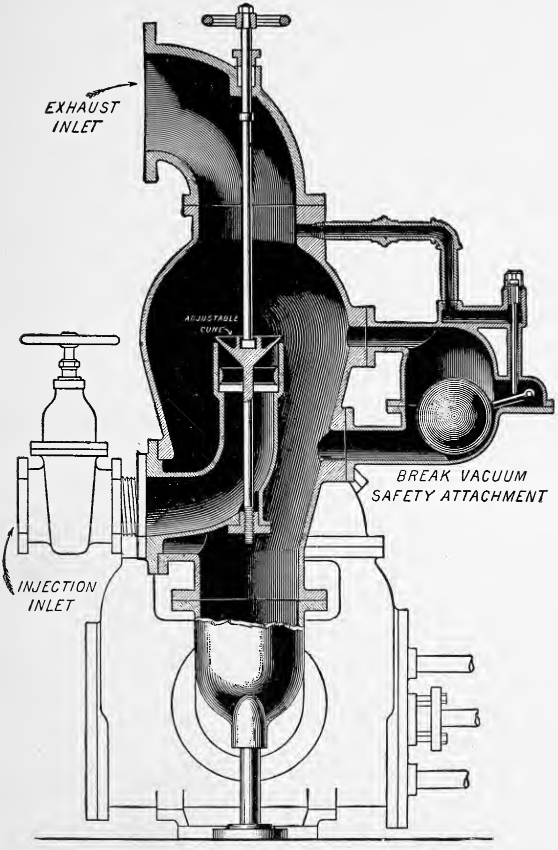

EXHAUST
INLET
ADJUSTABLE
CONE
INJECTION
INLET
BREAK VACUUM
SAFETY ATTACHMENT

FIGURE 53.

What is a vacuum breaker?

It is an attachment fastened to the side of a condenser consisting of a float and air valve, and also as part of it a pipe connecting air valve to body of condenser, its purpose being that, if the water should rise above the safe limit, the float would be raised, which in turn would raise the air valve admitting air to condenser, thus breaking the vacuum and equalizing the outside and inside pressure and stopping the injection flow.

Why are vacuum breakers necessary?

Unless such an attachment is provided, the injection water would soon find its way back to the cylinder and cause damage. In some condensers the arrangement of injector neck will accomplish the same results.

When vacuum is broken, what course does the exhaust from engine take?

The vacuum being broken, the pressure will equalize and force open an exhaust valve which is so placed that, when condenser is in operation, it remains closed, but, when pressure is equalized, the exhaust forces open the valve and is allowed to go into atmosphere. This valve is usually of the swing-check type. When the cause is removed and vacuum is re-established, the pressure falls below the atmosphere and the valve is closed.

Why are condensers used?

In a non-condensing engine or an engine exhausting into atmosphere, the steam which has filled the cylinder during the stroke has to be forced out against the atmospheric pressure or at about 15 pounds per square inch.

By condensing the steam (which forms a vacuum), we relieve the piston of a greater part of this atmospheric pressure, allowing it to return with but little back pressure. If

we take, say, 12 pounds per square inch from the back pressure by condensing, we have practically added 12 pounds per square inch to the pressure forcing the piston.

Give two reasons why a condenser will fail to work.

The air pumps may not properly remove the air and water or there may be insufficient injection water.

Explain the working of an injector condenser.

The injector condenser consists of two conical nozzles, jointed by a straight neck and swelled at the upper end of the water nozzles. Within are the exhaust-steam nozzles, which form within the condenser a narrow, annular space for the entrance of the condensing water. The sides of the condenser are smoothly finished, as is the contracted neck below, to diminish the resistance of the water. When used in connection with a condensing engine, the air pump may be dispensed with, as steam of atmospheric pressure will flow into a vacuum at the rate of 1,600 feet per second. When the exhaust steam from the engine meets the thin film of water which enters by the annular space, it is instantly condensed. As the water passes down, the contracting outline of the condenser gradually brings it to a solid jet in the neck below, through which it rushes with a velocity due to its pressure.

The air which has entered the condenser with the water, or through leaky joints or stuffing boxes, together with the uncondensed vapor, is thus drawn into a contracting, hollow cone of water, until finally expelled through the neck. This latter, being straight for a distance, is virtually the air pump, having a solid column of water moving at a high speed. This is the steam condensed, and the vacuum is formed by a single process, and with greater certainty than in any other way. The air and vapor, having passed the contracted neck,

enter the tapering nozzle below, and, expanding therein, are prevented from returning to the condenser above.

The method of operation of the injector condenser when the engine is started is as follows: The exhaust steam expels the air from exhaust pipe and condenser. Then a jet of cold water from a pump or tank creates a vacuum which may be maintained by a head of water 10 feet fall. The discharged water passes off at a temperature of 110°, when vacuum is equal to 26 inches of mercury.

BULKLEY CONDENSER.

Describe the action of a Bulkley condenser.

The Bulkley condenser has a pipe, dropping 34 feet, which discharges water from the condenser. The weight of this column of water 34 feet high more than overbalances the atmospheric pressure, and the water will flow from the condenser into the air. If the injection water is within 20 feet of the condenser, the vacuum will lift the water into the condenser. If supply is lower than this, a pump must be used to force the water into the condenser. Between the injection pipe and the overflow is a cross pipe with a valve in it, which is used in starting up. To start up, open this valve, allowing the water to cross over into the overflow pipe, and shut this valve when vacuum enough is obtained to lift water into condenser. With this condenser, water cannot work over into the cylinder of the engine.

How do you start a condensing engine having an independent air pump?

Start up air pump first, to get up the vacuum, and then start the engine when ready. After engine is started, air pump can be speeded up, if needed, to keep up the vacuum.

Sometimes there is an atmosphere pipe from the exhaust pipe, so engine can be run either condensing or non-condensing. This pipe has an automatic check-valve which will close itself when a vacuum is in exhaust pipe. Such an engine can be run non-condensing, and, when the air pump is started and vacuum obtained, and valve to the condenser opened, and engine feels vacuum, then the check-valve will shut itself, and engine will be running condensing.

In stopping an engine that is run with an independent air pump, shut down engine first, then shut down air pump.

How do you start a condensing engine having a dependent air pump?

Open forced injection as the engine starts, and, when there is vacuum enough to lift the water through the main injection pipe, open the main injection valve slowly, and shut forced injection. The main injection should then be opened as the engine comes up to speed. The danger in handling such an engine is in getting more injection water than the pump can handle. In starting, the pump is moving very slowly. In stopping an engine with the dependent air pump, be sure and partially shut injection as the engine slows down. If this is not done, water might be drawn into the cylinder, and head might be knocked out.

VACUUM.

How is vacuum maintained?

The vacuum is maintained in the condenser by the exhaust steam being constantly condensed by either mixing with the cold injection water or by being brought in contact with the cooling surface of the tubes in the surface condenser. The vacuum is maintained in the condenser by the action

of the air pump. A perfect vacuum cannot exist, and in the condenser there is always more or less pressure from imperfect condensation and air passing in with the condensing water.

To produce a vacuum in a surface condenser, open the injection valve shortly before starting the engine, so that the circulating water may enter the condenser tubes and cool them. Then, when the engine is started, the exhaust steam comes in contact with the cooling surface of the tubes, and is condensed, then a vacuum is formed.

How is vacuum measured?

The vacuum is measured by inches in the height of a column of mercury, 2 inches of mercury equalling 1 pound pressure per square inch. Thus 10 inches of mercury means 10 pounds' pressure per square inch. The state of the vacuum is shown by the vacuum gauge attached to the condenser; and, if it be imperfect, the cause must be ascertained and the fault corrected. If the water in the hot well is above the ordinary temperature, more injection water must be admitted; and, if the vacuum continues imperfect, the case may be due to an air leak, the location of which the engineer must endeavor to discover. Very often the fault will be found in the joint of the injection pipe, the gland of which will require to be tightened. The joints of the condenser may be tested by holding a candle to them, the flame of which will be drawn in if the joints are leaky.

Is vacuum power?

A vacuum is not power, as all power in the steam engine is derived from the pressure of steam on the piston. If there is no resistance on one side of the piston, the entire pressure on the other side is available. Whenever there is resistance on one side of the piston, it must be deducted from the pressure on the other side.

The temperature of the overflow from air pump to hot well should not be over 100° F.

Water will be lifted 1 foot for each inch of vacuum.

VACUUM GAUGE.

How is vacuum recorded?

The vacuum is recorded by a vacuum gauge connected with the condenser and piped to the engine-room. It registers the vacuum in inches. Inches are used instead of pounds, because they correspond with the mercury column, the mercury column being always used to measure the pressure of the atmosphere. A mercury column is frequently used in place of a vacuum gauge. With a perfect vacuum a column of mercury 30 inches high will be supported by the atmosphere. Vacuum gauges are usually graduated to agree with the scale of the barometer, and the vacuum is usually stated in inches of mercury.

The absolute pressure of steam is measured from zero, and consists of the pressure indicated by the steam gauge (which is known as pressure above atmosphere).

CHAPTER VIII.

THE AMERICAN THOMPSON IMPROVED INDICATOR.

Leading Pulley.

The leading pulley consists of a wheel which leads the cord through the hole to the scored wheel, over which the cord can be run any possible angle to connect with the motion, wherever it may be. The pulley works in a sleeve which rotates in the stand according to adjustments required, and is held in its position and adjusted by a thumb-screw work-

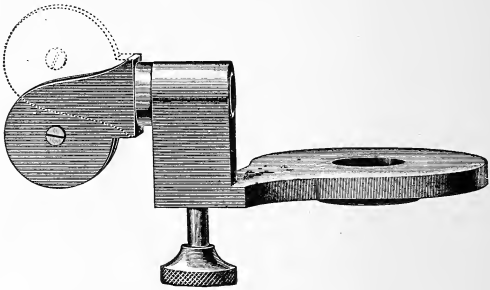


Figure 54.

ing in a groove on the sleeve, which acts as a binding screw. In this manner it is held in any desired position, and is free to revolve the moment the binding screw is loosened.

By means of a set screw the stand which carries the wheel can be adjusted to run the cord to any possible angle within a range of 360 degrees. This improved swivel pulley does

away with carrying pulleys from the fact that, no matter at what the angle of deflection may be or what direction it may be necessary to take the cord, it works smoothly.

The pulley face and face of the groove in the paper cylinder are always at the proper position, one with the other, to take the cord to the motion, wherever it may be.

In high speed, short stroke, electric light engines, great range of adjustment is generally necessary, as considerable

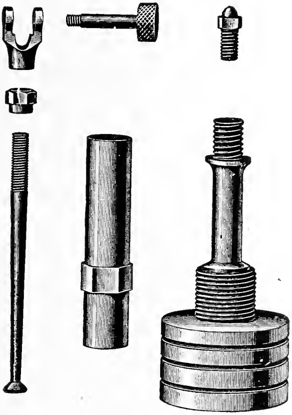


FIGURE 55.

trouble is often experienced, on engines running 300 revolutions per minute, in arranging the cord so as to use independent arcs, making connections so no distortion of diagrams shall be given.

PISTON.

The stem of the piston is constructed throughout of steel, the head being of a special hard bronze composition. The

upper part consists of a sleeve which acts as a guide in the cylinder cap.

The piston is connected with the pencil lever by a connecting rod having a cross-head at the upper end acting as a yoke to connect to the pencil lever. This cross-head is held in place by a small hexagon lock-nut. The top of the connecting rod being threaded permits of the raising and lowering of the cross-head and forms a means of adjusting the position of the atmospheric line on the diagram.

The lower end of the connecting rod forms a socket which rests on the ball stud which is adjustable in the piston stem. This gives a perfect ball-and-socket joint, and provides means for taking up the lost motion.

The piston is grooved for water packing, and is made as light as is consistent with the strength necessary to prevent expansion from pressure.

Cylinder.

The cylinder in which the piston travels is also made of a special hard bronze composition, which differs slightly from the piston head and produces a uniform expansion.

The cylinder is held securely at one end, having sufficient space between the cylinder and outer casing to form a suitable steam jacket.

Coupling.

The connection to the indicator cock consists of a swivel coupling having a tail piece which is screwed into the lower end of the cylinder, provided with a shoulder against which the inner flange of the coupling proper rests, forming a perfect swivel coupling, and is a decided improvement over the form of coupling having the right and left hand thread.

Springs.

The springs are made of the finest quality of steel wire, and are wound on a mandrel and tempered in the most careful manner.

All the springs are wound on mandrels from 4 to 4½ threads to the inch, and thereby give more wire to each

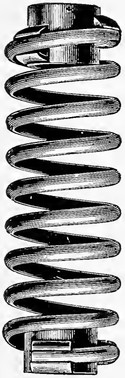


Figure 56.

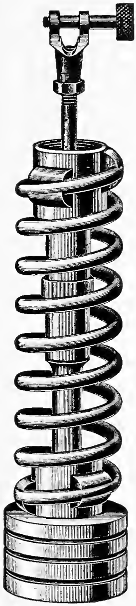


Figure 57.

spring, and a consequent less strain than if wound, as in springs of other indicators, on mandrels two to three threads to the inch.

All springs used in other instruments, whether double, single, or having a steel bead for bottom end when connected, and under steam pressure, do not possess the freedom of movement claimed, but are, in fact, as rigid as those made with double heads.

All springs made by this manufacturer are scaled providing for vacuum, and the capacity of any spring can be ascertained by the following general rule: Multiply scale of spring by $2\frac{1}{2}$, and subtract 15, and the result will be the limit of pounds' steam pressure to which spring should be subjected. Example: 40-pound spring $\times\ 2\frac{1}{2} = 100 - 15 = 85$ pounds' pressure, capacity of a 40-pound spring.

To adapt the American Thompson Improved Indicator to all pressures, springs are made to any desired scale. The following are the most generally used: 6, 8, 10, 12, 16, 20, 24, 30, 32, 40, 48, 50, 56, 60, 64, 70, 72, 80, 100, 120, 150, 200. For pressures from 65 to 85 pounds a 40-pound spring is best adapted, for, as 40 pounds' pressure on a 40-pound spring will raise pencil 1 inch, 80 pounds' pressure on the same spring will raise pencil about two inches, which is the usual height of a diagram.

Vacuum Springs.

All springs are scaled providing for vacuum, but close experiments have shown that, from the fact that springs compress and elongate in unlike proportions, the regular pressure springs vary about 1 pound in 30, or about $3\frac{1}{3}$ per cent.

To Change Springs.

First unscrew the milled nut at the top of steam cylinder. Then take out piston, with arm and connections. Disconnect pencil lever and piston by unscrewing the small knurled-

headed screw which connects them. Remove the spring from the piston, substitute desired one, and put together in same manner, being careful, of course, to screw the spring up against shoulder, and down full to the piston head. This arrangement does not require the use of wrench or pin of any kind.

To change springs in all other instruments, either a pin or wrench must be inserted between the coils of the spring, disconnecting the piston. By reason of the form of the coils not over one-sixteenth of an inch throw can be got by the pin or wrench at one time. When the piston is hot, the trouble attending such an operation can be imagined. The length of the springs varies according to scale, and requires no adjustment of atmospheric line. Furthermore, in the American Thompson Improved Indicator the ball-and-socket joint is adjusted to scale with each spring a complete vacuum, or its equivalent, 14.7 pounds; and this adjustment need never be changed. But in other instruments, every time a spring is changed, this adjustment must necessarily be changed, and the readjustment, to show a vacuum with each spring, rests with the party using indicator.

Maximum Safe Pressures to which Springs can be subjected when used with $\frac{1}{2}$ Square Inch Area Piston.

Scale of Spring.	Pounds per Square Inch.	Scale of Spring.	Pounds per Square Inch.
8	6	50	110
10	10	60	135
12	14	64	145
16	23	72	160
20	33	80	175
24	45	100	215
30	60	120	260
32	65	150	330
40	85	200	425
48	105		

All springs scaled for $\frac{1}{2}$ square inch area piston.

When $\frac{1}{4}$ square inch area piston is used, the capacity of the spring is doubled.

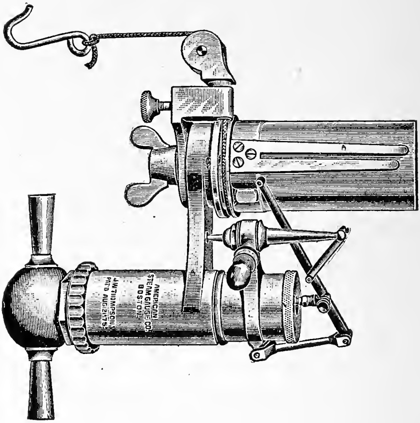


Figure 58.
With $1\frac{1}{2}$-inch Paper Drum.

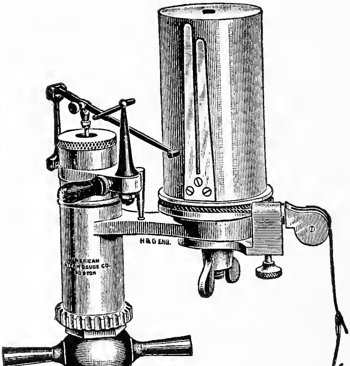


Figure 59.
Outside View.

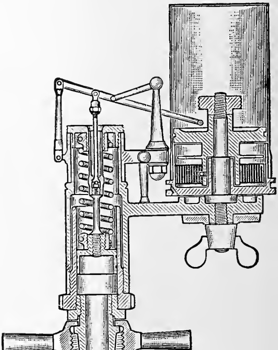


Figure 60.
Inside View.

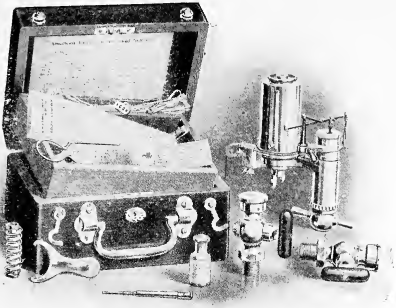
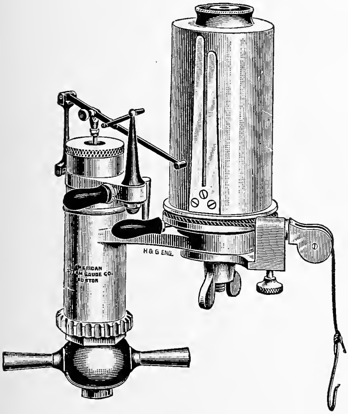


FIGURE 61.
THE AMERICAN THOMPSON IMPROVED INDICATOR COMPLETE WITH FITTINGS.



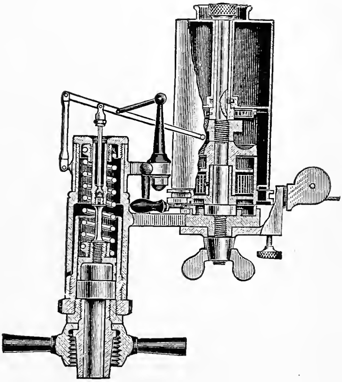


FIGURE 62. FIGURE 63.
THE AMERICAN THOMPSON IMPROVED INDICATOR WITH NEW IMPROVED DETENT MOTION (PATENTED).

The above illustrations show a well-known American Thompson Improved Indicator fitted with a new improved detent motion. This device possesses many valuable qualities, especially when applied to high-speed stationary engines, locomotives, and marine engines. In taking indicator diagrams from high-speed engines, it is very difficult sometimes to take off one card and put on another for the reason that the movement of the drum carriage must be stopped while changing the card, or while the drum is removed and put on again. This stopping and starting of the drum carriage of the ordinary indicator, whenever it becomes necessary to put on a new card, however accomplished, is usually attended by many vexatious happenings and disagreeable results. This is wholly obviated by using the new improved detent motion, as the drum carriage, after it is once connected with the reducing motion, need not be disconnected until desired. In taking cards from locomotive and marine engines, it is usually much more difficult to connect and disconnect the drum carriage with the reducing motion than it is with the stationary engines. In taking cards from marine engines, it is often very desirable or necessary, on account of close quarters and heat, to take the drum off the indicator in order to put on a new card, and this results in the spoiling of the fit of the drum of the ordinary indicator, and thereby causing it to run out of true,—a very objectionable feature, which the new detent motion entirely obviates, as the drum fit on the spindle is a long, lubricated bearing, well adapted for wear.

The object of the reducing wheel is to reduce accurately the motion of an engine cross-head to that required for a paper drum of an indicator, and to give the required length of diagram, regardless of the engine stroke. If either the

indicator or reducing motion is not correct, the cards are useless and deceptive. Hence the first step towards obtaining the true state of affairs in a steam cylinder is an indicator that will show the pressure and a correct reducing motion by which diagrams can be taken, so that an in-

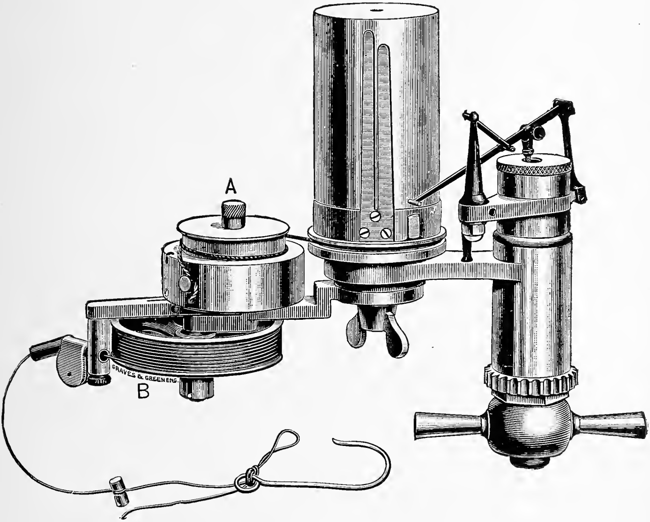


FIGURE 64.
THE AMERICAN THOMPSON IMPROVED INDICATOR WITH AMERICAN IDEAL REDUCING WHEEL.

telligent engineer can interpret them, adjust the valves, and figure the power developed.

This wheel is made of aluminum, brass, and steel, combining lightness and strength,—two essential features. The wheel drum from which the cord passes to the cross-head

is only $2\frac{3}{4}$ inches in diameter, and is made of aluminum. The coil spring for the take-up is in a separate case, and connected by a three-to-one gear with the cord-wheel spindle, so that, while the light aluminum cord-wheel makes three revolutions, the spring makes but one. The spring can be adjusted to any desired tension to keep the cord taut on return stroke. The cord-wheel revolves on a steel screw,

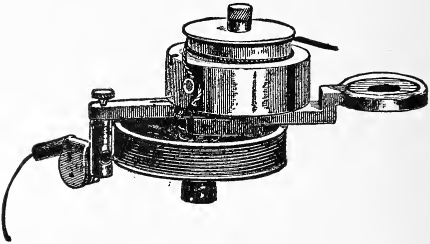


FIGURE 65.

the thread of which is the same pitch as the cord, so that, when the cord is drawn out, the wheel travels as it revolves. By this means the cord is wound smoothly on the drum, and passes straight through the guide pulley.

To use the reducing wheel on the indicator, remove the carrier pulley from the indicator and put the wheel on in place of it. Pass the drum cord around the small disk through the hole and under the holder, being careful to see that the cord is wound around the bushing or disk from the left, as shown in figure. Before attaching hook, see that cord on the wheel and indicator is taut at shortest part of the stroke, and that it will pull out a little farther than the longest part of the stroke.

The reducing wheel can be used in any place where it is most convenient, bearing in mind that the cord from it

to the cross-head should run in a straight line. In unhooking the cord, allow it to return slowly until the stop reaches the guide pulley.

Bushings of various sizes are furnished for small disks, so that cards can be taken from any length of stroke up to 72 inches.

THE AMERICAN PANTOGRAPH.

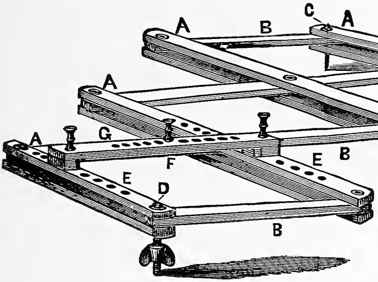


FIGURE 66.

The above cut shows another form of reducing motion, known as the pantograph, or lazy tongs, especially adapted for slow-speed and long-stroke Corliss or slide-valve engines.

DESCRIPTION.

It consists of a lazy-tongs system of levers. The long levers are of cherry, 16 inches between centres, $1\frac{1}{8}$ by $\frac{5}{16}$ in size. The hitch strip (*G*) is arranged so that it may be shifted in the holes (*E*), which brings a hitch pole (*F*) in a line passing through pivots (*C*, *D*).

There must be a vertical hole in the engine cross-head so that pivot (*C*) can be dropped into it.

A post must be set in the floor near the guides, with a socket in the top for pivot (*D*).

The stake socket must be level with and directly opposite the cross-head socket when the latter is at mid-stroke.

The indicator cord is hooked to the centre peg (*F*), and the stake should set at such a distance from the guides that the cord will lead off parallel with the guides. Otherwise, a guide pulley will be necessary.

When the pantograph is in motion, every point on a line cutting *C-D* has a true motion parallel with the guide, varying in distance from nothing at *D* to length of stroke at *C*.

It is only necessary to hitch the cord at a point on this line to give the right amount of motion to the cord. This point will be near (*D*) and within the range of adjustment of the strip *G*.

THE AMERICAN AMSLER'S POLAR PLANIMETER.

There are several other instruments which are used as accessories to the indicator, and which greatly facilitate the using of the instrument, one of which is Amsler's Polar Planimeter, as shown by the accompanying cut, for measuring the area of indicator diagrams. By using this instrument, the whole work of measuring a diagram can be done in one minute.

Engineers who have many indicator cards to work up cannot afford to be without a planimeter.

Directions for Using the Planimeter.

Press the point *A* slightly into the paper, not clear through, in such position that the tracer *B* will follow the desired line without bringing the roller *C* against any pro-

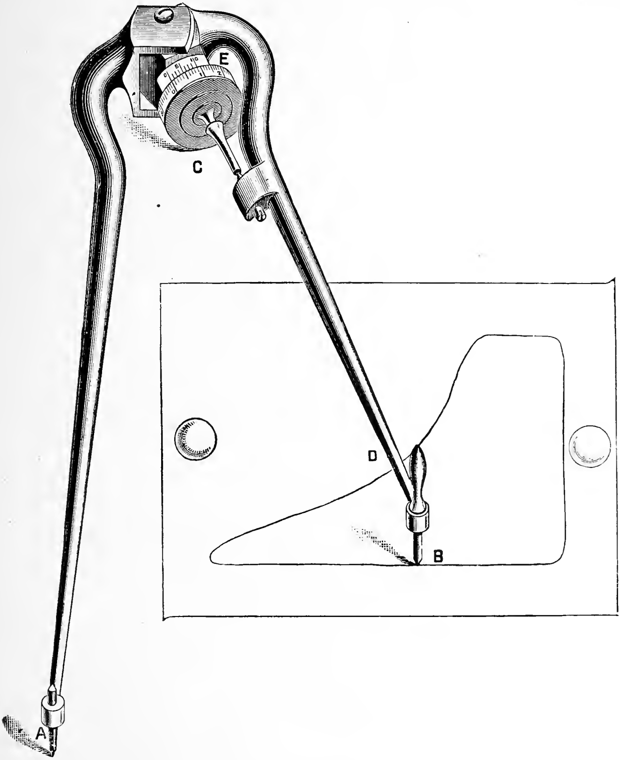


FIGURE 67.

jection. The roller must move on a continuous flat surface.

It is also well to fasten the diagram to a drawing board, or some other flat surface, by means of pins or springs, to prevent it from slipping.

Mark a starting point at any point on the outline of diagram *D*, set the tracer on that point, and place zero on the roller so it exactly coincides with the zero on vernier *E*.

Now trace the line, moving in the direction travelled by the hands of a watch: stop at the starting point and take the reading.

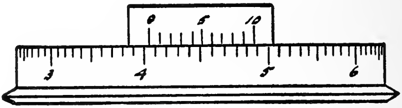


FIGURE 68.

First. Find the highest figure on the roller that has passed the zero on the vernier, moving to the left, which we will assume to be 4. Now the construction of instrument is such that each figure on the roller represents an equal number of square inches.

Second. Find the number of completed divisions between 4 on the roller and zero on the vernier, which we will assume to be 5.

Third. Find the number of the mark on the vernier which coincides with some mark on the roller, which in this case may be 6.

We now have the exact reading, 4.56, or $4 \frac{56}{100}$ inches area.

In measuring diagrams of more than ten inches area, add 10 to the result.

To those who are perfectly familiar with the instrument,

it is not necessary to place the zeros so they coincide, but take the reading as it is, and subtract it from the result. Should the second reading be less than the first, add 10 to the second reading before making the subtraction.

For instance, should the first reading be 8.42 and the second reading 2.68, add 10 to the second reading, thus: $2.68+10=12.68-8.42=4.26$ square inches.

If the area to be measured be very large, divide it by lines into areas of less than twenty square inches and take separate measurements.

If the drawing be to a scale, multiply the result by the square of the ratio number of the scale.

Should we desire to find the area of a plan containing 5 square inches, drawn to a scale of 100 rods to the inch, we square the ratio number and multiply by 5, thus: $100 \times 100 = 10{,}000 \times 5 = 50{,}000$ square rods.

In using the planimeter for indicator diagrams, for which it is specially adapted, we find the area of the diagram according to the foregoing directions, which we will assume to be 2.48. We now measure the length of the diagram parallel with the atmospheric line, which we will say in this case is 4 inches.

Now divide the area by the length. The quotient is the mean or average height of the diagram in inches, which is .62 inch. This we multiply by the scale of the indicator, which we will assume to be 40. The product gives us 24.8 pounds, mean pressure each square inch of the piston.

Expressed arithmetically, $2.48 \div 4 = .62 \times 40 = 24.8$.

It can also be used for measuring any regular or irregular plot or diagram.

INDICATORS.

What do the numbers stamped on an indicator spring signify?

The pressure necessary to raise the pencil 1 inch. A No. 40 spring makes a card 1 inch high for each 40 pounds of steam pressure at the engine.

How do you select the proper spring to use in indicator?

Divide the gauge pressure by 2.

What is the usual size of card?

4 inches long, 2 inches high.

How do you find what steam pressure a spring is good for?

Rule.—Multiply scale of spring (or number stamped upon it) by $2\frac{1}{2}$. From this product subtract 15 (never exceed this rule).

Example.—What spring should be used for an engine running under 100 pounds' boiler pressure?

$100 \div 2 = 50$ = spring for a card 2 inches high.

What is the maximum pressure you would allow a No. 50 spring to work under?

$50 \times 2\frac{1}{2} = 125 - 15 = 110$ pounds.

What are indicator cards?

It is a diagram showing at any part of the stroke the pressure acting upon the piston.

Before taking a card, what must be done?

Cylinder drips must be opened to free the cylinder of water. This precaution is taken so as not to injure the indicator.

What record is taken when taking a card?

Cylinder diameter, stroke, name and end of cylinder (as high pressure, left hand), number of spring, revolutions per minute, gauge pressure, and reading from vacuum gauge, if on a condensing engine.

What is taken first, atmospheric line or diagram, and why?

Steam is allowed to enter the cylinder of the instrument to warm it up before any cards are taken. The atmospheric line is taken after the cards are taken, as greater accuracy is obtained when all lines are taken near the same temperature.

How do you get an atmospheric line on card, and why used?

By swinging the pencil against the paper on drum while there is no steam in the indicator. It is used as a reference line for back pressure.

Where is the atmospheric line in a non-condensing engine in regard to card?

It is below the diagram, the distance corresponding to the back pressure.

Where is the atmospheric line in a condensing engine in regard to card?

It passes through the diagram near the lower edge. The distance between the lines represents the vacuum.

Why is the boiler pressure line drawn on the diagram?

To observe the drop in pressure between the boiler and cylinder.

How do you locate the clearance line in a diagram?

Rule.—Multiply total length of card by percentage of clearance, and set off this distance from end of diagram, drawing the clearance line at right angles to vacuum and atmospheric lines.

What may be learned by the indicator diagram?

It is used to determine not only the horse power and water consumption, but also shows the condition of valves, whether they are leaky or properly set, or leaky piston, etc.

What does the length of a card represent?

It is proportional to and represents the stroke of the engine.

What does the height represent?

It is proportional to and represents the boiler pressure.

What is meant by a full-load card?

A full-load card is taken when the engine is carrying all the load.

What is meant by a friction card?

A friction card is taken while the engine is running up to speed, and the load thrown off.

What does this show particularly, and why used?

It shows the amount of friction in reciprocating parts, and is used in calculating the efficiency of the engine.

What is the mean effective pressure?

Mean effective pressure is the average pressure which would have to act upon the piston throughout the entire stroke to cause the engine to develop the same power as under the indicated conditions, and is abbreviated M. E. P.

How is the mean effective pressure found from the card?

Rule.—Multiply area card by the spring used, and divide this product by length of card.

Example.—The card taken from one end of a cylinder is found to contain 2 square inches. A 60 spring was used. Length of card was $3\frac{1}{2}$ inches. What is the mean effective pressure?

$2 \times 60 = 120 \div 3\frac{1}{2} = 34.3$ M. E. P.

How may the mean effective pressure be found?

By use of ordinates or on equally spaced lines, and by use of the planimeter.

Explain the method of using ordinates.

The length of card is divided into 10 equal spaces. The distance from the lower line to the upper line of card is measured through the middle of these spaces. The length of these lines are added (in inches) and multiplied by scale of

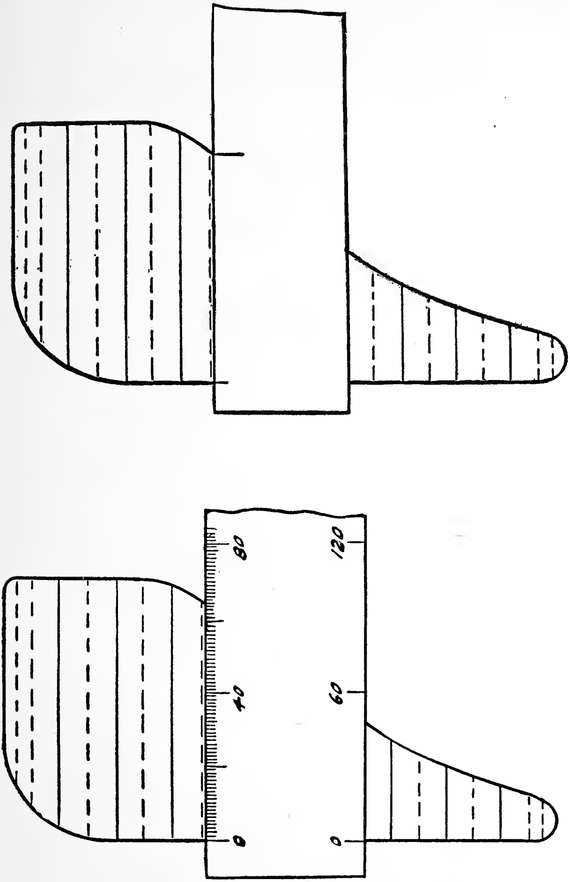


FIGURE 69.

spring used. This product is then divided by 10, or the number of spaces used, which gives the mean effective pressure.

Which is the more accurate?

The planimeter, as areas can, by careful work, be measured to $\frac{1}{100}$ of a square inch.

Where a loop appears on a diagram, and you are using ordinates, what must you look out for?

That the area of the loop is subtracted from the whole area. Using the planimeter, the instrument takes care of it by performing the subtraction automatically.

What is clearance?

It is the volume expressed in percentage of whole cylinder volume of the space between the face of piston, inner face of cylinder head, and volume of port to edge of valve seat.

How is the volume found?

Place engine at extreme stroke, and through indicator connection or any opening in top of cylinder pour in through a tunnel water which has been carefully weighed. Divide this weight of water by 62.5 (which is the weight of a cubic foot of water), which will give the number of cubic inches. Multiply area of cylinder by stroke in inches, which will give total volume of piston displacement. Divide the number of cubic inches of clearance by the piston displacement, the quotient will then be percentage of clearance.

Example.—What is the percentage of clearance in an engine cylinder 20 inches diameter by 36 inches stroke, weight of water to fill clearance space is 30 pounds?

```
62.5)30.000(.48=cubic feet volume of clearance.
     2500
     ----
      5000
      5000
      ----

        314.16=area 20-inch cylinder.
            36=stroke in inches.
      --------
       188496
       94248
      --------
      11309.76=cubic inches of piston displacement.

1728)11309.76(6.54=cubic feet displacement of piston.
     10368
     -----
      9417
      8640
      ----
       7776
       6912
       ----

6.54).4800(.0733=7.3 per cent. clearance.
      4578
      ----
       2220
       1962
       ----
        2580
        1962
        ----
```

What is a theoretical card?

A diagram showing perfect action of valves, expansion of steam, etc.

How is the piston speed in feet per minute found?

Rule.—Multiply stroke in inches by the number of strokes per minute and divide by 12. Number of strokes equal revolutions per minute; multiply by 2.

For accurate calculations for high pressure, what is done with the piston rod area?

If rod passes through one head, one-half area of rod is deducted from piston area; if rod passes through both heads, whole area of rod is deducted from area of piston.

What are the four periods of distribution of steam in an engine?

Admission, expansion, exhaust, and compression.

What is the most probable cause of a wavy expansion line?

May be vibration of the spring, or perhaps indicator piston sticks, or water in cylinder of engine.

What do sharp corners or changes in direction on a diagram signify?

Quick opening of valves.

What do round corners signify?

Slow opening of valves with wire drawing.

What is meant by wire drawing?

By wire drawing is meant throttling; caused by choked passages, ports too small, steam pipe too small, etc.

What is initial pressure?

It is pressure in the cylinder at the beginning of the stroke.

What is terminal pressure?

It is the pressure in the cylinder at the end of the stroke.

What is back pressure?

It is the pressure above atmosphere the steam on the live end has to counteract on the exhausting end in doing its work.

Are cards ever taken from anything but a steam engine?

Sometimes from the main steam pipe or receiver, condenser, or on a non-condensing engine from the exhaust pipe.

What is shown on the cards, when taken from the main steam pipe?

Whether or not steam has a free passage to the engine.

What is shown on the cards taken from the receiver?

The variation of steam pressure.

What is shown on the cards taken from the exhaust pipe or condenser?

Whether or not the exhaust steam has free passage from the cylinder.

Are cards ever taken from a steam pump?

Quite frequently cards are taken from the steam and water end of a steam pump. They show how accurately the valves work, and also the tightness of piston-rod stuffing boxes, and by comparison of both ends the amount of friction can be ascertained.

In attaching an indicator to water end, what precaution must be observed?

To place the indicator cylinder horizontally, to avoid air collecting in cylinder and acting as a cushion, which would not give accurate results.

What do you understand by atmospheric pressure?

It is the weight of air (expressed in pounds per square inch) surrounding the earth, and equals 14.7 pounds.

What is vacuum?

It is the absence of pressure.

What is gauge pressure?

Gauge pressure is the boiler pressure, as indicated by the steam gauge, or the pressure per square inch in the boiler.

Does the pressure affect the evaporation?

Yes, the lower the pressure, the lower the temperature necessary to boil water.

Does the temperature of steam affect the pressure?

An increased temperature raises the pressure.

What is wet saturated steam?

It is steam containing a percentage of moisture.

What is superheated steam?

It is steam having a temperature higher than that due to pressure.

Explain what is meant by ratio of expansion.

It is the number of times the volume of steam in the cylinder up to point of cut-off is expanded.

What is the average back pressure on a non-condensing engine?

Usually on an economical engine this is about 17 pounds absolute.

What is the average back pressure on a condensing engine?

Usually about 3 pounds absolute.

What is meant by the efficiency of an engine?

It is a comparison of the amount of feed water with the amount of steam taken from the diagram.

Explain what you understand a partial vacuum to be.

If air in a sealed vessel were pumped out, so that the gauge should read less than atmospheric pressure, a perfect vacuum would be contained in the vessel.

At what temperature will water evaporate?

Under atmospheric pressure of 14.7 pounds, water will evaporate at 212° F.

A cubic foot of water will make how many cubic feet of steam at atmospheric pressure?

It will make 1,646 cubic feet.

What occurs when steam is cooled?

It will condense into water.

DEFECTIVE DIAGRAMS.

An expansion curve that is higher than it should be may arise from a leaky valve, letting in steam after the cut-off takes place.

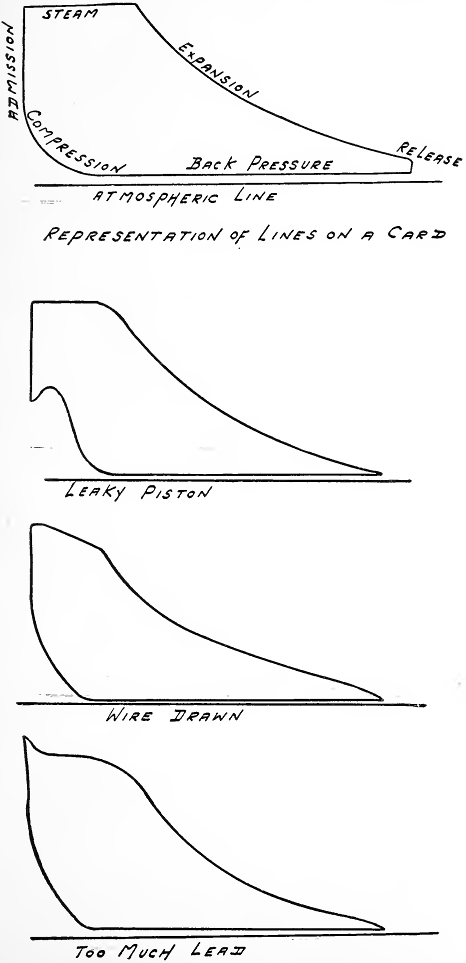


FIGURE 70.

An expansion curve that is lower than it should be may be caused by a leaky piston or it might be caused by a leaky valve.

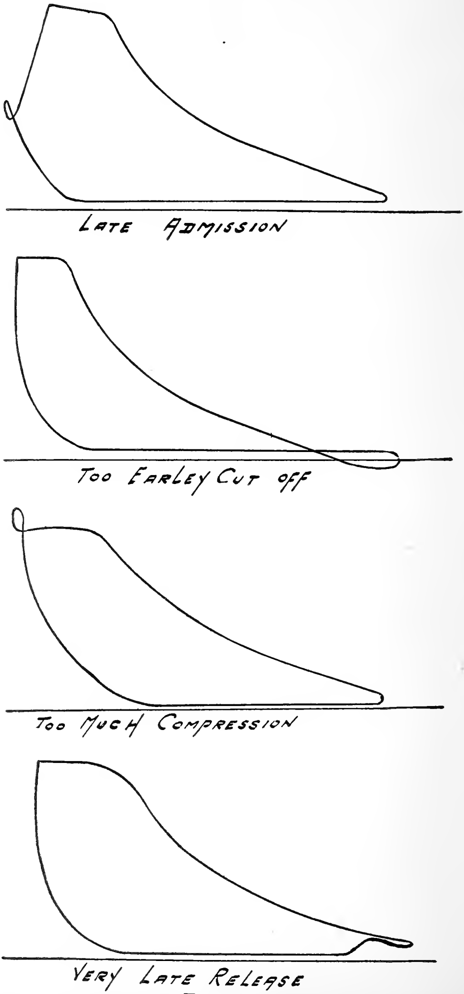
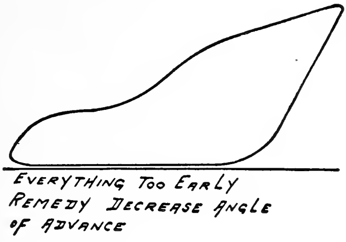


FIGURE 71.

Suppose you had a leaky valve and a leaky piston.

In that case, as a result the expansion curve may appear correct and not show the leak.



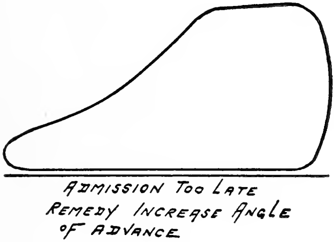


FIGURE 72.

Remedy is to set the eccentric back.

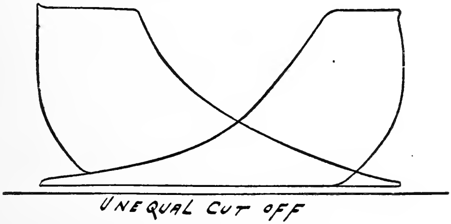
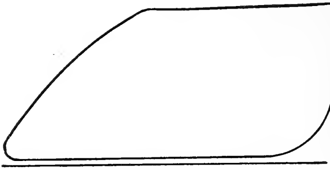
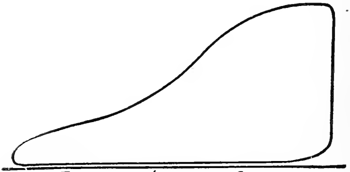


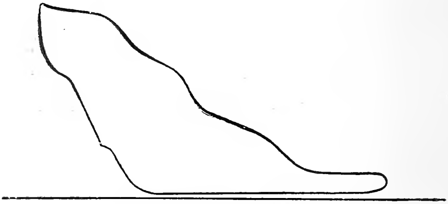
FIGURE 73.



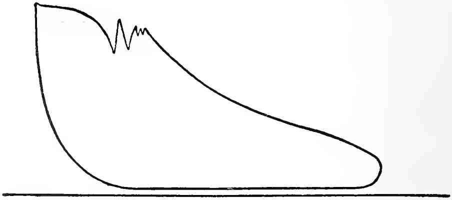
STEAM LAP TOO SMALL



EXHAUST LAP TOO SMALL

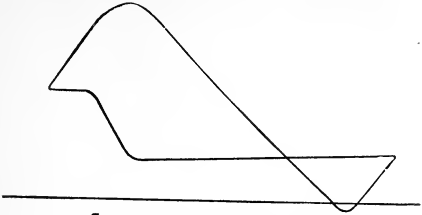


INDICATOR INERTIA

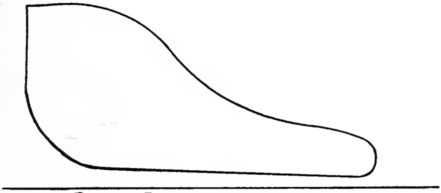


STICKING OF INDICATOR PISTON

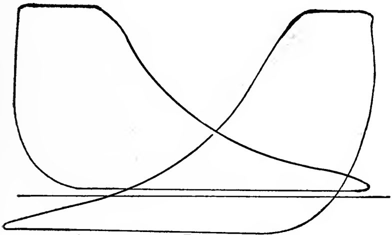
FIGURE 74.



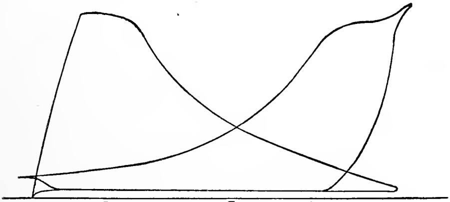
ECCENTRIC SLIPPED BACK



BACK PRESS TOO HIGH



ONE END CONDENCING



EXCENTRIC ROD TOO LONG

FIGURE 75.

How would you know if the valve did not have proper lead?

Lead would be shown by the piston moving a certain portion of the stroke before the steam line attained its greatest height. The upwards line from the admission line is at right angles instead of rising vertically, showing that the piston had moved a certain portion of its stroke before full pressure of steam was admitted.

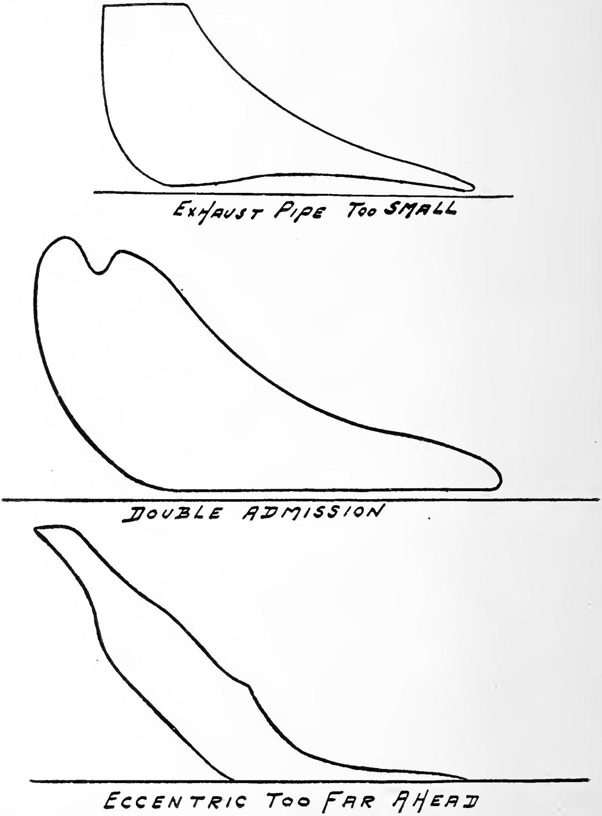


FIGURE 76.

Excessive lead is shown by the lap where compression curve extends up to the steam line. The lead carries the admission line above it on account of piston moving against the incoming steam.

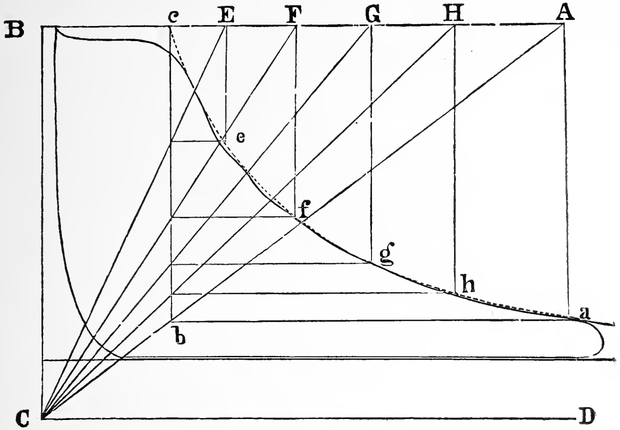


FIGURE 77.

How is a theoretical expansion curve on card constructed?

On the diagram lay off the line *CD* from the atmospheric line equal to 14.7 pounds (using same scale as spring in instrument when card was taken).

From the admission line draw *BC*, this distance representing the clearance (as found by preceding rule).

Draw *BA* parallel to *CD*, representing boiler pressure, plus 14.7 pounds, measured from *CD*.

Select any point, *g* on expansion line, and draw *gG* perpendicular to *CD* and intersecting *BA*. Draw *CG*. At *g* draw a line parallel to *CD* and intersecting *CG*. From

this point of intersection draw a line perpendicular to *CD* and intersecting *BA* at point *c*. This point is the theoretical point of cut-off. Select any point, *E*, on *BA*. Draw *CE*. Draw *Ee* perpendicular to *CD*. Where *CE* intersects *Cb*, draw a line parallel to *CD* to reach *Ee*. This is one point of the theoretical expansion curve.

Select any point, *F*, *H*, *A*, card. Draw in similar manner through these points thus found a curved line, which is the theoretical curve of expansion.

How do you figure the distance from end of diagram to clearance line?

Rule.—Multiply the length of card by the percentage of clearance.

Example.—What is the distance from clearance line to end of diagram on an engine having 6 per cent. clearance and length of diagram equals 3 inches?

$6\% = .06 \times 3 = .18$ inch.

If actual clearance is not known, how may it be found approximately by the theoretical expansion curve?

Select two points on the expansion line, *C* (card), *g*. Draw *Gg* and *cb* perpendicular to *CD*. From *g* draw a line parallel to *CD* and intersecting *cb*. From this intersection draw to *G*, extending line to cut *CD*, or at point *C*. Draw *BC* at the intersection, which is the clearance line.

HORSE POWER.

Rule.—To figure the horse power of an engine, certain data must be known, first, the mean effective pressure; second, the length of stroke in feet; third, the area of cylinder in square inches; and, fourth, the number of strokes per minute. The mean effective pressure is found directly from the cards taken (see rule). The length of stroke in feet is also found by rule previously given. The area of cylinder is found by multiplying the square of the diameter by .7854, and the number of strokes is found by multiplying the number of revolutions per minute by 2.

RULE FOR HORSE POWER.

Horse power (or 33,000 the constant) is an expression for work in foot pounds, and means the amount of power necessary to raise 33,000 pounds 1 foot in one minute.

Rule.—Multiply the M. E. P. by length of stroke in feet by the area of cylinder in square inches and by the number of strokes per minute. Divide this product by 33,000. The result is the indicated horse power of the engine.

By deducting the friction H. P. from the indicated H. P., the remainder will give the actual H. P.

Example.—A set of cards taken from a 12×36-inch engine gives as areas 4.1 and 4.0 square inches and is $3\frac{1}{2}$ inches long. A 40 spring was used, the engine running 112 revolutions per minute.

```
                           4.1
                           4.0 = area of cards.
                         2)8.1
                           4.05 = average area.
                             40 = spring.
length of card = 3.5)162.00(46.28 = M. E. P.
                     140
                      220
                      210
                       100         46.28 = M. E. P.
                        70             3 = length of stroke in ft.
       12               300       138.84
       12               280       113.09 = area of cylinder.
      144                         124956
               .7854             41652
                 144            13884
               31416           13884
              31416           15701.4156
              7854                   224 = strokes per minute.
             113.0976         628056624
                             314028312
                            314028312
                     33000)3517117.0944(106.57 = horse power.
                           33000
       112 = revs.          217117
         2                  198000
       224 = strokes.        191170
                             165000
                              261700
                              231000
```

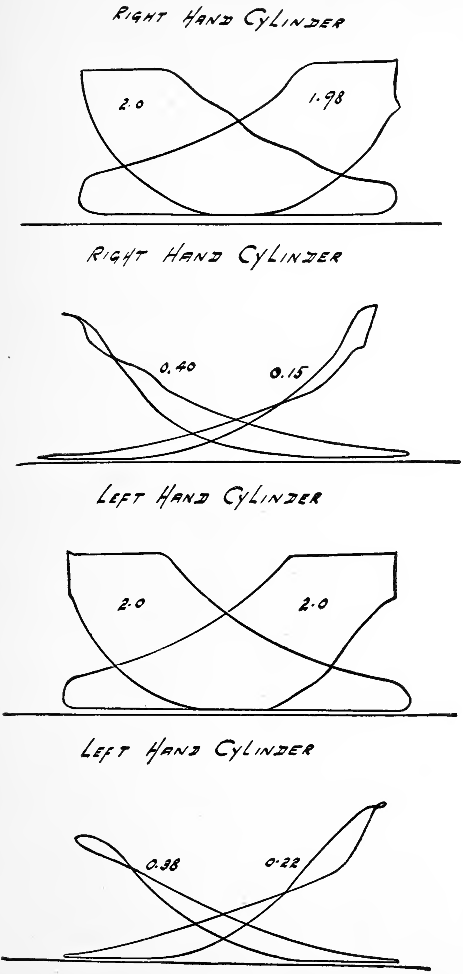

RIGHT HAND CYLINDER
2.0
1.98
RIGHT HAND CYLINDER
0.40
0.15
LEFT HAND CYLINDER
2.0
2.0
LEFT HAND CYLINDER
0.38
0.22

FIGURE 78.

These cards were taken from a 9 × 5½ double upright Sturtevant engine, boiler pressure 84 pounds, spring 60, revolutions full load 348, revolutions friction 350. Figure horse power for friction and full load efficiency.

FULL-LOAD CARDS.

R. H. cylinder.

```
                        2.00 = area head end.
                        1.98 = area crank end.
                      2)3.98
                        1.99 = average area.
                          60 = spring.
length of card = 2.8)119.40(42.642 = M. E. P.
                     112
                       74
                       56
                       180
                       168
                        120
                        112
                          80
                          56
```

5½ inches = 5.5 = length of stroke.

```
12)5.5(.458, call this .46 (of a foot).
   48
    70
    60
    100
     96
```

```
      348=revolutions.
        2
      ---
      696=strokes per minute.

    42.64=M. E. P.
      .46=stroke in feet.
   ------
    25584
   17056
  -------
  19.6144
    63.62=area 9-inch cylinder.
  --------
   392288
  1176864
  588432
 1176864
-----------
1247.868128
      696=strokes per minute.
-----------
    7487208
   11230812
   7487208
33,000)868516.128(26.31=H. P. of R. H. cylinder.
       66000
       ------
       208516
       198000
       ------
        105161
         99000
        ------
          61612
          33000
          -----
```

```
L. H. cylinder.          2.00 = area head end.
                         2.00 = area crank end.
                       2)4.00
                         2.00 = average area.
                           60 = spring.
length of card = 2.8)120.00(42.8 = M. E. P.
                       112
                         80            42.8 = M. E. P.
                         56             .46 = stroke in feet.
                         240           2568
                         224          1712
                                     19.688
                                      63.62 = area cylinder.
                                      39376
                                    118128
                                    59064
                                  118128
                                  1252.55056
                                         696 = strokes per minute.
                                    751530
                                  1127295
                                  751530
                        33,000)871774.80(26.41 = H. P. of L. H.
                               66000                  cylinder.
                               211774
                               198000
26.31 = R. H.                   137740
26.41 = L. H.                   132000
52.72 = total horse power        57400
           developed.            33000
```

Friction Cards.

R. H. cylinder.

```
                          .40 = area head end.
                          .15 = area crank end.
                       2).55
                         .275  = average area.
                            60 = spring.
length of card = 2.8)16.500(5.89 = M. E. P.
                      140
                       250
                       224
                        260
                        252

                                       5.89 = M. E. P.
                                        .46 = stroke in feet.
                                       3534
                                      2356
                                      2.7094
                                     63.62 = area cylinder.
                                        540
                                      1620
                                      810
                                    1620
                                    171.7740
                                       696 = strokes per minute.
                                   103062
                                  154593
                                 103062
                                 119551.92
```

```
33,000)119551.92(3.62=H. P. friction for R. H. cylinder.
        99000
        205519      L. H. cylinder.
        198000                          .38=area head end.
         75190                          .22=area crank end.
         66000                        2).60
                                        .30=average area.
                                         60
              length of card=2.8)18.00(6.4=M. E. P.
                                  168
                                   120
                                   112
                   6.4=M. E. P.
                   .46=stroke in feet.
                   384
                  256
                  2.944
                  63.62=area of cylinder.
                   5888
                  17664
                 8832
                17664
                187.29728
                    696=strokes per minute.
              1123782
             1685673
            1123782
     33,000)130358.712(3.95=H. P. friction for L. H. cyl-
            99000               inder.
            313587
            297000
             165870
             165000
```

3.62 = H. P. R. H. cylinder.
3.95 = H. P. L. H. cylinder.
7.57 = Total friction H. P.

friction 100 × 7.57 = 757.00

total H. P. developed = 52.72)757.00(14.3 = per cent. of friction.

$$
\begin{array}{r}
5272 \\
\hline
22980 \\
21088 \\
\hline
18920 \\
15816 \\
\hline
3104
\end{array}
$$

$$
\text{efficiency} = \begin{array}{r} 100 \\ 14.3 \\ \hline 85.7 \end{array} \text{ per cent.}
$$

total horse power developed = 52.72
total friction H. P. = 7.57
percentage of friction = 14.3 per cent.
efficiency = 85.7 per cent.

How do you find the quantity of steam used by an engine per minute?

Rule.—Multiply area of cylinder in square inches by the piston speed in inches per minute and by the numerator of the fraction of cut-off. Divide this product by 1,728 times the denominator of the fraction of cut-off. Multiply this quotient by 60 for quantity of steam used per hour.

Example.—Find the quantity of steam used per hour by a 10 × 20 engine running 80 revolutions per minute and cutting off at $\frac{1}{3}$ stroke.

10 = diameter cylinder.

10

100

.7854

78.5400 = area of cylinder.

20 = stroke.

1570.80

160 = number of strokes.

942480

157080

251328.00

1 = numerator of $\frac{1}{3}$ cut-off.

251328

1728 = cubic inches per cubic foot.

3 = denominator of $\frac{1}{3}$ cut-off.

5184

5184)251328(48.48 = cubic feet per minute.

20736

43968

41472

24960

20736

42240

41472

48.48

60

2908.80 = cubic feet per hour.

Why do you wish to know the amount of water used?

The amount of feed water shows the total quantity furnished the boiler, and the indicator cards show actual amount used by the engine. The difference of these two amounts is the quantity used by leaky stuffing boxes, leakage in valve and piston, joints, etc.

How do you find the quantity of water evaporated into steam per hour?

Rule.—Multiply area of cylinder in square inches by the speed of the piston in inches per minute, and the numerator of the fraction of cut-off times 60, divide this product by 1,728 times the volume of steam (at given pressure) times the denominator of the fraction of cut-off.

Example.—Find the quantity of water evaporated into steam per hour to supply a 26×30 engine running 80 revolutions per minute, under 90 pounds per square inch boiler pressure, cutting off $\frac{5}{12}$ stroke.

$$\begin{array}{r l}
26 & = \text{diameter of cylinder.} \\
26 & \\
\hline
156 & \\
52 & \\
\hline
676 &
\end{array}
\qquad\qquad
\begin{array}{r l}
.7854 & \\
676 & \\
\hline
47124 & \\
54978 & \\
47124 & \\
\hline
530.9304 & = \text{area of cylinder.}
\end{array}$$

```
   530.93
        30=stroke in inches.
  ---------
  15927.90
       160=strokes per minute (80 revolutions×2).
  ---------
  9556740
 1592790
 ----------
 2548464.00
        60=minutes per hour.
 ----------
152907840
         5=numerator of fraction 5/12.
---------
764539200

   1728=cubic inches 1 cubic foot.
  258.9=relative volume of steam at 90 pounds'
 ------
  15552      pressure (see steam table).
 13824
 8640
4356
--------
537379.2
     12=denominator of fraction 5/12.
--------
10747584
5373792
---------
6448550.4

6448550)764539200.0(103.05=lbs. of steam used
        6448550                   per hour.
        --------
         19684200
         19345650
         ---------
           33855000
           32242750
           ---------
            1612250
```

CHAPTER IX.

HYDRAULIC ELEVATOR.

Explain a hydraulic elevator.

Hydraulic elevators consist of a piston rod and cross-head which carries a set of travelling sheaves and a set of fixed sheaves. Now, when water is applied to the piston, it would pull these sheaves apart, causing the end of the cable in the hatchway to rise with the cage attached, at a speed much faster than that at which the piston travelled. The speed of cage would travel eight times as fast as the piston, or eight times as far. With this arrangement, when connected to the city mains, the water after being used was wasted.

A great advantage was gained by the introduction of what was called the pressure tank, water being pumped into this tank, with inlet and outlet pipes taken from the bottom of the tank to prevent the escape of any of the air. There is also a glass to show the height of the water in the tank and pressure gauge. Air would be pumped into the tank, one-third air and two-thirds water. There are two tanks needed, a pressure tank and an overflow tank. After the water is used in the elevator machine, it goes into an overflow tank, and is then pumped again into the pressure tank. The pipes connected to it are the pipe to the elevator machine, a discharge pipe from the pump, a pipe from the elevator machine to the overflow tank, a pipe to the automatic governor on steam pipe to pump. The pump is operated automatically by a diaphragm valve in the steam pipe. To get air into the pressure tank, open the check-valve which is attached to pump above the

suction valve and below the discharge valve, or open suction pipe from the overflow tank to pump. Water and air will then be pumped into the pressure tank. If you do not wish for the water line to rise, open overflow from pressure tank into overflow tank.

Elevator machines are single acting. The weight of the car and people brings it down. This system would not work if the pressure tank was full of water.

What is a hydraulic plunger elevator?

A hoisting machine consists of a cylinder equal in length to the rise of the car and erected vertically beneath it. The cylinder is fitted with a plunger, to the upper end of which the car is fastened.

The plunger is made of finished wrought or cast iron pipe. The water is admitted at the top of this cylinder through an improved, balanced double valve, with a water space of one inch between the plunger and cylinder and pressing upon the bottom of plunger. The weight of the car is counterbalanced. The plunger elevators take the least power to operate them.

CHAPTER X.

USEFUL INFORMATION.

$\sqrt[3]{}$ = cube root, or that the number contained beneath it must have the cube root extracted; as, $\sqrt[3]{343} = 7$

Pounds = cubic feet × 62.425
Gallons = cubic feet × 7.48
Pressure of water = height in feet × .4335

Height in feet = pressure × 2.309
Tons = cubic feet ÷ 35.88
Tons = gallons 268.36
1 cubic foot = 62.425 pounds.
1 cubic foot = 7.48 gallons.
1 cubic foot = 1728 cubic inches.
1 cubic inch of water = .036 pound.
27.71 cubic inches water weighs 1 pound.
1 gallon = 231 cubic inches.
1 gallon = .833 imperial gallon.
1 gallon weighs 8.33 pounds.
1 ton (long) = 2,240 pounds.
1 ton (short) = 2,000 pounds.
1 ton = 35.88 cubic feet.
1 ton = 268.36 gallons.

About 125 gallons of petroleum oil is equal to a ton of good coal in making steam.

26.37 cubic feet of steam weighs 1 pound: at atmospheric pressure 13.81 cubic feet of air weighs 1 pound,—so that steam

exhausting into the atmosphere is equal in weight to practically one-half that of the air.

Doubling the diameter of a pipe or a cylinder increases the area and contents 4 times.

Cubic inches of cast iron $\times$ .26 = weight in pounds.
Cubic inches wrought iron $\times$ .28 = weight in pounds.
Cubic inch steel $\times$ .28 = weight in pounds.
Cubic inches copper $\times$ .32 = weight in pounds.
Cubic inches brass $\times$ .30 = weight in pounds.
Cubic inches $\times$ .41 = weight in pounds.
Cubic inches $\times$ .0036 = gallons.

Cubic feet of coal $\times$ .0345 = tons in weight.

The square of the circumference of a rope in inches $\times$ .66 = safe load in tons.

The square of the diameter of a round bar of iron in inches $\times$ 2.64 = weight in pounds per foot.

The square of the side of a square bar of iron in inches $\times$ 3.36 = weight in pounds per foot.

Weight of 1 gallon of water = 8.35 pounds.

1 cubic inch of air = .31 grain's weight.

1 cubic inch of mercury = .49 pound's weight.

A column of water 1 inch square, 1 foot high, weighs .433 pounds.

A column of water 27.71 inches in height exerts 1 pound pressure per square inch.

To reduce decimals of a foot to inches.

Example.—Reduce .55 of a foot to inches.

$.55 \times 12 = 6.60 = 6.6$ inches.

To reduce inches to a decimal part of a foot.

$6.6 \div 12 = .55$ of a foot.

To find the number of feet of belting in a roll.

Add the diameter of hole to the outside diameter of the roll, multiply this sum by the number of turns in the roll, and multiply this product by .1309.

To find the size and speed of pulleys.

Rule.—Multiply the diameter of driver by the number of revolutions of driver, and divide this product by diameter of driven.

Example.—A 30-inch diameter pulley, making 180 revolutions per minute, drives a counter-shaft with a 12-inch pulley. What is the speed of the counter-shaft?

```
     180
      30
12)5400(450=revolutions of counter-shaft.
    48
     60
     60
```

Example.—A pulley 30 inches diameter on a main shaft running 180 revolutions per minute is required to drive a counter-shaft 450 revolutions per minute. What will be the diameter of pulley?

Rule.—Multiply the diameter of driver by the number of revolutions of the driver, and divide the product by revolutions of driven.

```
       180
        30
450)5400(12 = diameter in inches of pulley on
    450          counter-shaft.
     900
     900
```

Example.—A counter-shaft with a 12-inch pulley is required to run 450 revolutions per minute. The revolutions of main shaft is 180. What size pulley must be used on the main shaft?

Rule.—Multiply diameter of driven pulley by the number of revolutions of driven, and divide this product by the number of revolutions of driver.

```
       450
        12
       900
      450
180)5400(30 = diameter of pulley in inches on main
    540          shaft.
```

RULES.

How many cubic inches are contained in a gallon?

231 cubic inches.

How many cubic inches are contained in a cubic foot?

1,728 cubic inches.

How many pounds are there in one gallon of water?

8.34 pounds.

What is the weight of a column of water 1 inch square and 1 foot high?

.432 pound.

How do you find the number of cubic inches per stroke?

Square the diameter, multiply this product by the stroke in inches, and multiply this last product by .7854.

How do you find the number of gallons per stroke?

Square the diameter, multiply this product by the length of stroke in inches, and multiply this last product by .7854. Divide this value by 231.

How do you find the number of gallons per minute?

Multiply the square of the diameter by the stroke in inches per minute, by the number of strokes per minute, and by .7854. Divide the product by 231.

Example.—A pump having a 10-inch cylinder and 12-inch stroke makes 40 strokes per minute. If the pump is double-acting, how many gallons will it pump per minute?

```
                    10   =inches diameter cylinder.
                    10   =inches diameter cylinder.
                   ----
                   100   =square of cylinder.
                  .7854  =constant.
                  -----
                  78.54
                    12   =stroke in inches.
                 ------
                 15708
                 7854
                 ------
                 942.48                       [double acting).
No. cu. in.          80  =number of strokes × 2 (for
in 1 gal.=231)75398.40(326.4 =gallons per minute.
              693
              ---
               609
               462
               ----
               1478
               1386
               ----
                 924
                 924
                 ---
```

How do you find the horse power necessary to lift a given quantity of water a given height?

Multiply the quantity in gallons by the height in feet, and this product multiply by 8.34. Divide this last product by 33,000.

Example.—From a tank containing water we wish to raise 100 gallons per minute to a height of 10 feet. What horse power is necessary, friction not considered?

$$
\begin{array}{rl}
100 & = \text{gallons to be raised.} \\
12 & = \text{feet high.} \\
\hline
1200 & \\
8.34 & = \text{weight of water per gallon.} \\
\hline
4800 & \\
3600 & \\
9600 & \\
\hline
33{,}000)10008.00(.3 & \\
99000 & \\
\hline
10800 &
\end{array}
$$

Usually 25 per cent. is added for friction, therefore adding to

$$.3 \times 25\% = .075 + .3 = .375 \text{ H. P.}$$

$+$ = plus, or the sign of addition; as, $1605 + 924 = 2529$

$-$ = minus, or the sign of subtraction; as, $1605 - 924 = 681$

$\times$ = multiply, or the sign of multiplication; as,—

$$
\begin{array}{r}
1605 \\
924 \\
\hline
6420 \\
3210 \\
14445 \\
\hline
1483020
\end{array}
$$

$\div$ or $\frac{12}{2}$ = divide, or the sign of division; as,—

$$\begin{array}{r}1605)1483020(924\\ \underline{14445}\\ 3852\\ \underline{3210}\\ 6420\\ \underline{6420}\end{array}$$

. = decimal point, or by its position it indicates the value of a number; as,—

157 = one hundred and fifty-seven.
15.7 = fifteen and seven-tenths.
1.57 = one and fifty-seven hundredths.
.157 = one hundred and fifty-seven thousandths.

$(20)^2$ = to be squared, or that the number is to be multiplied by itself; as,—

$$\begin{array}{r}(20)^2 = 20\\ \underline{20}\\ 400\end{array}$$

$(20)^3$ = to be cubed, or that the number is to be multiplied by itself twice; as,—

$$\begin{array}{r}(20)^3 = 20\\ \underline{20}\\ 400\\ \underline{20}\\ 8000\end{array}$$

: :: : = a proportion, as 4 : 12 :: 8 : 24, and is read, Four is to twelve as eight is to twenty-four.

$\sqrt{}$ = a radial sign, and means that a root is to be extracted from the number contained beneath it. When no prefix is observed, it applies to square root, as $\sqrt{81} = 9$.

Square Root.

Rule.—Separate the given number into as many divisions or periods as possible of two figures each. Find the greatest square in the left-hand period, write the root of it at the right of the given number, same as for a quotient, and subtract the second power from the left-hand period. Bring down the next period to the right of the remainder for a new dividend, and double the root already found for a trial divisor. Find how many times this divisor is contained in the dividend (exclusive of the right-hand figure), and write the quotient as the next figure of the root. Annex the last root figure to the trial divisor for the true divisor, multiply by the last root figure, and subtract the product from the dividend. To the remainder bring down the next period for a new dividend. Double the root already found for a new trial divisor, and continue the operation as before until all the periods have been brought down.

Example.—Find the square root of 278784.

```
     √278784(528
       25
     102)287
         204
     1048)8384
          8384
```

Proof. $528 \times 528 = 278784$.

A power of a number is the result obtained by taking that quantity a certain number of times for a factor. The 1st power is the root, or the number involved. The 2d power is the product multiplied by itself. The 3d power is the root used three times.

Find the 5th power of 4.

$$\begin{array}{r l}
4 & = \text{1st power.} \\
\underline{4} & \\
16 & = \text{2d power.} \\
\underline{4} & \\
64 & = \text{3d power.} \\
\underline{4} & \\
256 & = \text{4th power.} \\
\underline{4} & \\
1024 & = \text{5th power.}
\end{array}$$

Avoirdupois or Commercial Weight.

27.34375 grains	=1 drachm.
16 drachms	=1 ounce=437.5 grains.
16 ounces	=1 pound=256 drachms=7,000 grains.
28 pounds	=1 quarter=448 ounces.
4 quarters	=1 cwt.=112 lbs.
20 cwts.	=1 ton=80 quarters=2,240 lbs.

Long Measure.

By law the United States standards of length and weight are made equal to the British.

12 inches	=1 foot.
3 feet	=1 yard=36 inches=.9143919 metre.
5½ yards	=1 rod, pole, or perch=16½ feet.
40 rods	=1 furlong.
8 furlongs	=1 mile=5,280 feet=63,360 inches.
3 miles	=1 league.

Inches and their Equivalent Decimal Values in Parts of a Foot.

Inches.	Fraction of Foot.	Decimal Part of Foot.
1	$\frac{1}{12}$	.0833
2	$\frac{1}{6}$	.1667
3	$\frac{1}{4}$	.25
4	$\frac{1}{3}$	.3333
5	$\frac{5}{12}$	.4167
6	$\frac{1}{2}$	.5
7	$\frac{7}{12}$	.5833
8	$\frac{2}{3}$	.6667
9	$\frac{3}{4}$	.75
10	$\frac{5}{6}$	.8333
11	$\frac{11}{12}$	.9167
12	1	1.0

Fractional Parts of an Inch and their Equivalent Decimal Values in Parts of a Foot.

Fractions of an Inch.	Decimals of Foot.	Fractions of an Inch.	Decimals of Foot.
$\frac{1}{16}$	.0052	$\frac{9}{16}$	.0469
$\frac{1}{8}$	.0104	$\frac{5}{8}$	.0521
$\frac{3}{16}$	.0156	$\frac{11}{16}$	.0573
$\frac{1}{4}$	.0208	$\frac{3}{4}$	.0625
$\frac{5}{16}$	.0260	$\frac{13}{16}$	.0677
$\frac{3}{8}$	.0313	$\frac{7}{8}$	.0729
$\frac{7}{16}$	.0365	$\frac{15}{16}$	.0781
$\frac{1}{2}$	.0417	1	.0833

Square or Land Measure.

144 square inches = 1 square foot.
9 square feet = 1 square yard.
$30\frac{1}{4}$ square yards = 1 square rod.
40 square rods = 1 rood.
4 roods = 1 acre = 43,560 square feet.

In the United States surveys a SECTION OF LAND is 1 mile square, or 640 acres.

A square acre is 208.71 feet on each side.

A circular acre is 235.504 feet in diameter.

Cubic or Solid Measure.

1,728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.

A cord of wood, being 4 × 4 × 8 feet, contains 128 cubic feet. A ton, 2,240 pounds of Pennsylvania anthracite coal in size for domestic use, occupies from 41 to 43 cubic feet; bituminous coal, 44 to 48 cubic feet; coke, 80 cubic feet.

Liquid Measure.

4 gills = 1 pint.
2 pints = 1 quart.
4 quarts = 1 gallon = 231 cubic inches.

A cylinder 3½ inches in diameter and 6 inches high will hold almost exactly one quart, and one 7 inches in diameter and 6 inches high will hold very nearly one gallon.

This United States gallon is only .8333 of the British imperial gallon. A cubic foot contains about 7½ United States gallons.

Dry Measure.

2 pints = 1 quart.
8 quarts = 1 peck.
4 pecks = 1 bushel.

Four quarts in dry measure contain 268.8 cubic inches, or .96945 of the British imperial gallon. The flour barrel should contain 3.75 cubic feet and 196 pounds.

Mensuration.

Mensuration of Surfaces.

Area of any parallelogram	= base $\times$ perpendicular height.
Area of any triangle	= base $\times \frac{1}{2}$ perpendicular height.
Area of any circle	= diameter$^2 \times$ .7854.
Area of sector of circle	= arc $\times \frac{1}{2}$ radius.
Area of segment of circle	= area of sector of equal radius, less area of triangle.
Surface of cylinder	= area of both ends + length $\times$ circumference.
Surface of cone	= area of base + circumference of base $\times \frac{1}{2}$ slant height.
Surface of sphere	= diameter$^2 \times$ 3.1415.
Surface of frustum	= sum of girt at both ends $\times \frac{1}{2}$ slant height + area of both ends.

Properties of the Circle.

Diameter $\times$ 3.14159 = circumference.
Diameter $\times$ .8862 = side of an equal square.
Diameter $\times$ .7071 = side of an inscribed square.
Diameter$^2 \times$ .7854 = area of circle.
Radius $\times$ 6.28318 = circumference.
Circumference $\div$ 3.14159 = diameter.

The circle contains a greater area than any plane figure, bounded by an equal perimeter or outline.

The areas of circles are to each other as the squares of their diameters.

Any circle whose diameter is double that of another contains four times the area of the other.

Area of a circle is equal to the area of a triangle whose base equals the circumference and perpendicular equals the radius.

Mensuration of Solids.

Cylinder	= area of one end × length.
Sphere	= cube of diameter × .5236.
Segment of sphere	= square root of the height added to three times the square of radius of base × by height and by .5236.
Cone or pyramid	= area of base × $\frac{1}{3}$ perpendicular height.
Frustum of a cone	= product of diameter of both ends + sum of their squares × perpendicular height × .2618.
Frustum of a pyramid	= sum of the areas of the two ends + square root of their product × by $\frac{1}{3}$ of the perpendicular height.
Solidity of wedge	= area of base × $\frac{1}{2}$ perpendicular height.
Frustum of a wedge	= $\frac{1}{2}$ perpendicular height × sum of the areas of the two ends.
Solidity of a ring	= thickness + inner diameter × square of the thickness × 2.4674.

CEMENTS.

Fine cast-iron borings	98 parts
Flour of sulphur	1 part
Sal-ammoniac	1 "

Mix dry, and, when required for use, dissolve in boiling water. This cement sets quickly.

A Slow-setting Cement.

Fine cast-iron borings	197 parts
Flour of sulphur	1 part
Sal-ammoniac	2 parts

Mix dry, and, when required for use, mix with boiling water. For any cement the iron borings should be perfectly free from grease, and, if nothing but greasy material is available, boil it in a strong solution of common washing soda.

For Mouth-pieces of Clay Retorts.

Three-fourths fire clay, one-fourth iron borings. When wanted for use, mix with ammoniacal water. Use no sulphur.

For Steam and Gas Pipes.

The following mixture is said to make a cement for steam and gas pipes impermeable by air or water, hot or cold:—

Finely powdered graphite	6 parts
Slacked lime	3 "
Sulphur	8 "
Boiled oil	7 "

The mass must be well kneaded until the mixture is perfect.

A gallon of water (United States standard) weighs $8\frac{1}{3}$ pounds, and contains 231 cubic inches.

A cubic foot of water weighs $62\frac{1}{2}$ pounds, and contains 1,728 cubic inches, or $7\frac{1}{2}$ gallons.

Each *nominal* horse power of boilers requires 1 cubic foot of water per hour.

In calculating horse power of steam boilers, consider for:—

Tubular boilers 15 square feet of heating surface equivalent to 1 horse power.

Flue boilers 12 square feet of heating surface equivalent to 1 horse power.
Cylinder boilers 10 square feet of heating surface equivalent to 1 horse power.

To find the area of a piston, square the diameter and multiply by .7854.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

Every stroke an engine makes above its regular speed is a waste of steam. An engine, when load is thrown off, increases its speed, and decreases it when additional load is put on.

Steam is calculated in pounds per square inch above the atmospheric pressure of 14.7. The nearer the line of expansion approaches that of the atmosphere, the greater the power derived from the volume of steam.

TABLE FOR THE CONVERSION OF DEGREES OF THE CENTIGRADE THERMOMETER INTO DEGREES OF FAHRENHEIT'S SCALE.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
0	32.	26	78.8	51	123.8	76	168.8
1	33.8	27	80.6	52	125.6	77	170.6
2	35.6	28	82.4	53	127.4	78	172.4
3	37.4	29	84.2	54	129.2	79	174.2
4	39.2	30	86.0	55	131.0	80	176.0
5	41.0	31	87.8	56	132.8	81	177.8
6	42.8	32	89.6	57	134.6	82	179.6
7	44.6	33	91.4	58	136.4	83	181.4
8	46.4	34	93.2	59	138.2	84	183.2
9	48.2	35	95.0	60	140.0	85	185.0
10	50.0	36	96.8	61	141.8	86	186.8
11	51.8	37	98.6	62	143.6	87	188.6
12	53.6	38	100.4	63	145.4	88	190.4
13	55.4	39	102.2	64	147.2	89	192.2
14	57.2	40	104.0	65	149.0	90	194.0
15	59.0	41	105.8	66	150.8	91	195.8
16	60.8	42	107.6	67	152.6	92	197.6
17	62.6	43	109.4	68	154.4	93	199.4
18	64.4	44	111.2	69	156.2	94	201.2
19	66.2	45	113.0	70	158.0	95	203.0
20	68.0	46	114.8	71	159.8	96	204.8
21	69.8	47	116.6	72	161.6	97	206.6
22	71.6	48	118.4	73	163.4	98	208.4
23	73.4	49	120.2	74	165.2	99	210.2
24	75.2	50	122.0	75	167.0	100	212.0
25	77.0						

Properties of Saturated Steam.

Gauge Pressure, Pounds per Square Inch.	Absolute Pressure, Pounds per Square Inch.	Temperature Fahrenheit.	Total Heat above 32° F. In the Water h Heat-units.	Total Heat above 32° F. In the Steam H Heat-units.	Latent Heat L $=H-h$ Heat-units.	Relative Volume of Water at 39° F. = 1.	Volume Cubic Feet in 1 Pound of Steam.	Weight of 1 Cubic Foot Steam, Pound.
5.3	20	227.9	197.0	1151.5	954.4	1231.	19.72	.05070
10.3	25	240.0	209.3	1155.1	945.8	998.4	15.99	.06253
15.3	30	250.2	219.7	1158.3	938.9	841.3	13.48	.07420
20.3	35	259.2	228.8	1161.0	932.2	727.9	11.66	.08576
25.3	40	267.1	236.9	1163.4	926.5	642.0	10.28	.09721
30.3	45	274.3	244.3	1165.6	921.3	574.7	9.21	.1086
35.3	50	280.9	251.0	1167.6	916.6	520.5	8.34	.1198
40.3	55	286.9	257.2	1169.4	912.3	475.9	7.63	.1311
45.3	60	292.5	262.9	1171.2	908.2	438.5	7.03	.1422
50.3	65	297.8	268.3	1172.8	904.5	406.6	6.53	.1533
55.3	70	302.7	273.4	1174.3	900.9	379.3	6.09	.1643
60.3	75	307.4	278.2	1175.7	897.5	355.5	5.71	.1753
65.3	80	311.8	282.7	1177.0	894.3	334.5	5.37	.1862
70.3	85	316.0	287.0	1178.3	891.3	315.9	5.07	.1971
75.3	90	320.0	291.2	1179.6	888.4	299.4	4.81	.2080
80.3	95	323.9	295.1	1180.7	885.6	284.5	4.57	.2188
85.3	100	327.6	298.9	1181.8	882.9	271.1	4.36	.2296
90.3	105	331.1	302.6	1182.9	880.3	258.9	4.16	.2403
95.3	110	334.5	306.1	1184.0	877.9	247.8	3.98	.2510
100.3	115	337.8	309.5	1185.0	875.5	237.6	3.82	.2617
105.3	120	341.0	312.8	.9	873.2	228.3	3.67	.2724
110.3	125	344.1	316.0	1186.9	870.9	219.6	3.53	.2830
115.3	130	347.1	319.1	1187.8	868.7	211.6	3.41	.2936
120.3	135	350.0	322.1	1188.7	866.6	204.2	3.29	.3042
125.3	140	352.8	325.0	1189.5	864.6	197.3	3.18	.3147
130.3	145	355.5	327.8	1190.4	862.6	190.9	3.07	.3253
135.3	150	358.2	330.6	1191.2	860.6	184.9	2.98	.3358
140.3	155	360.7	333.2	1192.0	858.7	179.2	2.89	.3463
145.3	160	363.3	335.9	.7	856.9	173.9	2.80	.3567
150.3	165	365.7	338.4	1193.5	855.1	169.0	2.72	.3671
155.3	170	368.2	340.9	1194.2	853.3	164.3	2.65	.3775
160.3	175	370.5	343.4	.9	851.6	159.8	2.58	.3879
165.3	180	372.8	345.8	1195.7	849.9	155.6	2.51	.3983
170.3	185	375.1	348.1	1196.3	848.2	151.6	2.45	.4087
175.3	190	377.3	350.4	1197.0	846.6	147.8	2.39	.4191
180.3	195	379.5	352.7	.7	845.0	144.2	2.33	.4296
185.3	200	381.6	354.9	1198.3	843.4	140.8	2.27	.4400
190.3	205	383.7	357.1	1199.0	841.9	137.5	2.22	.4503
195.3	210	385.7	359.2	.6	840.4	134.5	2.17	.4605
200.3	215	387.7	361.3	1200.2	838.9	131.5	2.12	.4707

Area of Circles.

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
1-64	.000192	5.	19.635	12.	113.098	19.	283.529
1-32	.000767	.$\frac{1}{8}$	20.629	.$\frac{1}{8}$	115.466	.$\frac{1}{8}$	287.272
1-16	.003068	.$\frac{1}{4}$	21.6476	.$\frac{1}{4}$	117.859	.$\frac{1}{4}$	291.04
1-8	.012272	.$\frac{3}{8}$	22.6907	.$\frac{3}{8}$	120.277	.$\frac{3}{8}$	294.832
3-16	.027612	.$\frac{1}{2}$	23.7583	.$\frac{1}{2}$	122.719	.$\frac{1}{2}$	298.648
1-4	.049087	.$\frac{5}{8}$	24.8505	.$\frac{5}{8}$	125.185	.$\frac{5}{8}$	302.489
5-16	.076699	.$\frac{3}{4}$	25.9673	.$\frac{3}{4}$	127.677	.$\frac{3}{4}$	306.355
3-8	.110447	.$\frac{7}{8}$	27.1086	.$\frac{7}{8}$	130.192	.$\frac{7}{8}$	310.245
7-16	.15033	6.	28.2744	13.	132.733	20.	314.16
1-2	.19635	.$\frac{1}{8}$	29.4648	.$\frac{1}{8}$	135.297	.$\frac{1}{8}$	318.099
9-16	.248505	.$\frac{1}{4}$	30.6797	.$\frac{1}{4}$	137.887	.$\frac{1}{4}$	322.063
5-8	.306796	.$\frac{3}{8}$	31.9191	.$\frac{3}{8}$	140.501	.$\frac{3}{8}$	326.051
11-16	.371224	.$\frac{1}{2}$	33.1831	.$\frac{1}{2}$	143.139	.$\frac{1}{2}$	330.064
3-4	.441787	.$\frac{5}{8}$	34.4717	.$\frac{5}{8}$	145.802	.$\frac{5}{8}$	334.102
13-16	.518487	.$\frac{3}{4}$	35.7848	.$\frac{3}{4}$	148.49	.$\frac{3}{4}$	338.164
7-8	.661322	.$\frac{7}{8}$	37.1224	.$\frac{7}{8}$	151.202	.$\frac{7}{8}$	342.25
15-16	.690292	7.	38.4846	14.	153.938	21.	346.361
1.	.7854	.$\frac{1}{8}$	39.8713	.$\frac{1}{8}$	156.7	.$\frac{1}{8}$	350.497
.$\frac{1}{8}$	.99402	.$\frac{1}{4}$	41.2826	.$\frac{1}{4}$	159.485	.$\frac{1}{4}$	354.657
.$\frac{1}{4}$	1.2272	.$\frac{3}{8}$	42.7184	.$\frac{3}{8}$	162.296	.$\frac{3}{8}$	358.842
.$\frac{3}{8}$	1.4849	.$\frac{1}{2}$	44.1787	.$\frac{1}{2}$	165.13	.$\frac{1}{2}$	363.051
.$\frac{1}{2}$	1.7671	.$\frac{5}{8}$	45.6636	.$\frac{5}{8}$	167.99	.$\frac{5}{8}$	367.285
.$\frac{5}{8}$	2.0739	.$\frac{3}{4}$	47.1731	.$\frac{3}{4}$	170.874	.$\frac{3}{4}$	371.543
.$\frac{3}{4}$	2.4053	.$\frac{7}{8}$	48.7071	.$\frac{7}{8}$	173.782	.$\frac{7}{8}$	375.826
.$\frac{7}{8}$	2.7612	8.	50.2656	15.	176.715	22.	380.134
2.	3.1416	.$\frac{1}{8}$	51.8487	.$\frac{1}{8}$	179.673	.$\frac{1}{8}$	384.466
.$\frac{1}{8}$	3.5466	.$\frac{1}{4}$	53.4563	.$\frac{1}{4}$	182.655	.$\frac{1}{4}$	388.822
.$\frac{1}{4}$	3.9761	.$\frac{3}{8}$	55.0884	.$\frac{3}{8}$	185.661	.$\frac{3}{8}$	393.203
.$\frac{3}{8}$	4.4301	.$\frac{1}{2}$	56.7451	.$\frac{1}{2}$	188.692	.$\frac{1}{2}$	397.609
.$\frac{1}{2}$	4.9087	.$\frac{5}{8}$	58.4264	.$\frac{5}{8}$	191.748	.$\frac{5}{8}$	402.038
.$\frac{5}{8}$	5.4119	.$\frac{3}{4}$	60.1322	.$\frac{3}{4}$	194.828	.$\frac{3}{4}$	406.494
.$\frac{3}{4}$	5.9396	.$\frac{7}{8}$	61.8625	.$\frac{7}{8}$	197.933	.$\frac{7}{8}$	410.973
.$\frac{7}{8}$	6.4918	9.	63.6174	16.	201.062	23.	415.477
3.	7.0686	.$\frac{1}{8}$	65.3968	.$\frac{1}{8}$	204.216	.$\frac{1}{8}$	420.004
.$\frac{1}{8}$	7.6699	.$\frac{1}{4}$	67.2008	.$\frac{1}{4}$	207.395	.$\frac{1}{4}$	424.558
.$\frac{1}{4}$	8.2958	.$\frac{3}{8}$	69.0293	.$\frac{3}{8}$	210.598	.$\frac{3}{8}$	429.135
.$\frac{3}{8}$	8.9462	.$\frac{1}{2}$	70.8823	.$\frac{1}{2}$	213.825	.$\frac{1}{2}$	433.737
.$\frac{1}{2}$	9.6211	.$\frac{5}{8}$	72.7599	.$\frac{5}{8}$	217.077	.$\frac{5}{8}$	439.364
.$\frac{5}{8}$	10.3206	.$\frac{3}{4}$	74.6621	.$\frac{3}{4}$	220.354	.$\frac{3}{4}$	443.015
.$\frac{3}{4}$	11.0447	.$\frac{7}{8}$	76.5888	.$\frac{7}{8}$	223.655	.$\frac{7}{8}$	447.69
.$\frac{7}{8}$	11.7933	10.	78.54	17.	226.981	24.	452.39
4.	12.5664	.$\frac{1}{8}$	80.5158	.$\frac{1}{8}$	230.331	.$\frac{1}{8}$	457.115
.$\frac{1}{8}$	13.3641	.$\frac{1}{4}$	82.5161	.$\frac{1}{4}$	233.706	.$\frac{1}{4}$	461.864
.$\frac{1}{4}$	14.1863	.$\frac{3}{8}$	84.5409	.$\frac{3}{8}$	237.105	.$\frac{3}{8}$	466.638
.$\frac{3}{8}$	15.033	.$\frac{1}{2}$	86.5903	.$\frac{1}{2}$	240.529	.$\frac{1}{2}$	471.436
.$\frac{1}{2}$	15.9043	.$\frac{5}{8}$	88.6643	.$\frac{5}{8}$	243.977	.$\frac{5}{8}$	476.259
.$\frac{5}{8}$	16.8002	.$\frac{3}{4}$	90.7628	.$\frac{3}{4}$	247.45	.$\frac{3}{4}$	481.107
.$\frac{3}{4}$	17.7206	.$\frac{7}{8}$	92.8858	.$\frac{7}{8}$	250.948	.$\frac{7}{8}$	485.479
.$\frac{7}{8}$	18.6655	11.	95.0334	18.	254.47	25.	490.875
—	—	.$\frac{1}{8}$	97.2055	.$\frac{1}{8}$	258.016	.$\frac{1}{8}$	495.796
—	—	.$\frac{1}{4}$	99.4022	.$\frac{1}{4}$	261.587	.$\frac{1}{4}$	500.742
—	—	.$\frac{3}{8}$	101.6234	.$\frac{3}{8}$	265.183	.$\frac{3}{8}$	505.712
—	—	.$\frac{1}{2}$	103.8691	.$\frac{1}{2}$	268.803	.$\frac{1}{2}$	510.706
—	—	.$\frac{5}{8}$	106.1394	.$\frac{5}{8}$	272.448	.$\frac{5}{8}$	515.726
—	—	.$\frac{3}{4}$	108.4343	.$\frac{3}{4}$	276.117	.$\frac{3}{4}$	520.769
—	—	.$\frac{7}{8}$	110.7537	.$\frac{7}{8}$	279.811	.$\frac{7}{8}$	525.838
						26.	530.93

TABLE OF STANDARD DIMENSIONS OF WROUGHT-IRON WELDED PIPE FOR STEAM, GAS, OR WATER.

Inside Diameter (Nominal).	Actual Outside Diameter.	Thickness.	Actual Inside Diameter.	Internal Circumference.	External Circumference.	Length of Pipe per Sq. Ft. of Inside Surface.	Length of Pipe per Sq. Ft. of Outside Surface.	Internal Area.	External Area.	Length of Pipe containing One Cubic Foot.	Weight per Foot of Length.	Number of Threads per Inch of Screw.
	Inches.	Inches.	Inches.	Inches.	Inches.	Feet.	Feet.	Inches.	Inches.	Feet.	Pounds.	
$\frac{1}{8}$	0.405	0.068	0.270	0.848	1.272	14.15	9.44	0.0572	0.129	2,500.0	0.243	27
$\frac{1}{4}$	0.54	0.088	0.364	1.144	1.696	10.50	7.075	0.1041	0.229	1,385.0	0.422	18
$\frac{3}{8}$	0.675	0.091	0.494	1.552	2.121	7.67	5.657	0.1916	0.358	751.5	0.561	18
$\frac{1}{2}$	0.84	0.109	0.623	1.957	2.652	6.13	4.502	0.3048	0.554	472.4	0.845	14
$\frac{3}{4}$	1.05	0.113	0.824	2.589	3.299	4.635	3.637	0.5333	0.866	270.0	1.126	14
1	1.315	0.134	1.048	3.292	4.134	3.679	2.903	0.8627	1.357	166.9	1.670	$11\frac{1}{2}$
$1\frac{1}{4}$	1.66	0.140	1.380	4.335	5.215	2.768	2.301	1.496	2.164	96.25	2.258	$11\frac{1}{2}$
$1\frac{1}{2}$	1.9	0.145	1.611	5.061	5.969	2.371	2.01	2.038	2.835	70.65	2.694	$11\frac{1}{2}$
2	2.375	0.154	2.067	6.494	7.461	1.848	1.611	3.355	4.430	42.36	3.667	$11\frac{1}{2}$
$2\frac{1}{2}$	2.875	0.204	2.468	7.754	9.032	1.547	1.328	4.783	6.491	30.11	5.773	8
3	3.5	0.217	3.067	9.636	10.996	1.245	1.091	7.388	9.621	19.49	7.547	8
$3\frac{1}{2}$	4.0	0.226	3.548	11.146	12.566	1.077	0.955	9.887	12.566	14.56	9.055	8
4	4.5	0.237	4.026	12.648	14.137	0.949	0.849	12.730	15.904	11.31	10.728	8
$4\frac{1}{2}$	5.0	0.247	4.508	14.153	15.708	0.848	0.765	15.939	19.635	9.03	12.492	8
5	5.563	0.259	5.045	15.849	17.475	0.757	0.629	19.990	24.299	7.20	14.564	8
6	6.625	0.280	6.065	19.054	20.813	0.63	0.577	28.889	34.471	4.98	18.767	8
7	7.625	0.301	7.023	22.063	23.954	0.544	0.505	38.737	45.663	3.72	23.410	8
8	8.625	0.322	7.982	25.076	27.096	0.478	0.444	50.039	58.426	2.88	28.348	8
9	9.688	0.344	9.001	28.277	30.433	0.425	0.394	63.633	73.715	2.26	34.077	8
10	10.75	0.366	10.019	31.475	33.772	0.381	0.355	78.838	90.762	1.80	40.641	8

Standard Lap-welded Charcoal Iron Boiler Tubes.

Outside Diameter.	Standard Thickness.	Nearest Birmingham Wire Gauge Thickness.	Inside Diameter.	Inside Circumference.	Outside Circumference.	Length of Tube per Sq. Foot, Inside Surface.	Length of Tube per Sq. Foot, Outside Surface.	Inside Area.	Outside Area.	Nominal Weight per Foot.
Inches.	Inches.	Wire Gauge.	Inches.	Inches.	Inches.	Feet.	Feet.	Sq. Inches.	Sq. Inches.	Pounds.
1	.072	15	0.85	2.68	3.14	4.46	3.81	0.57	0.78	.70
1¼	.072	15	1.10	3.47	3.92	3.45	3.05	0.96	1.22	.90
1½	.083	14	1.33	4.19	4.71	2.86	2.54	1.39	1.76	1.24
1¾	.095	13	1.56	4.90	5.49	2.44	2.18	1.91	2.40	1.66
2	.095	13	1.80	5.66	6.28	2.11	1.90	2.55	3.14	1.91
2¼	.095	13	2.05	6.48	7.06	1.85	1.69	3.31	3.97	2.16
2½	.109	12	2.28	7.17	7.85	1.67	1.52	4.09	4.90	2.75
2¾	.109	12	2.53	7.95	8.63	1.50	1.39	5.03	5.94	3.04
3	.109	12	2.78	8.74	9.42	1.37	1.27	6.08	7.06	3.33
3¼	.120	11	3.01	9.46	10.21	1.26	1.17	7 12	8.29	3.96
3½	.120	11	3.26	10.24	10.99	1.17	1.09	8.35	9.62	4.28
3¾	.120	11	3.51	11.03	11.78	1.08	1.01	9.68	11.04	4.60
4	.134	10	3.74	11.75	12.56	1.02	.95	10.99	12.56	5.47
4½	.134	10	4.24	13.32	14.13	.90	.84	14.12	15.90	6.17
5	.148	9	4.72	14.81	15.70	.80	.76	17.49	19.63	7.58
6	.165	8	5.69	17.90	18.84	.67	.63	25.50	28.27	10.16
7	.165	8	6.65	20.91	21.99	.57	.54	34.80	38.48	11.90
8	.165	8	7.63	23.98	25.13	.50	.47	45.79	50.26	13.65
9	.180	7	8.61	27.05	28.27	.44	.42	58.29	63.61	16.76
10	.203	6	9.57	30.07	31.41	.39	.38	71.97	78.54	21.00
11	.220	5	10.56	33.17	34.55	.36	.34	87.47	95.03	25.00
12	.229	4½	11.54	36.26	37.69	.33	.31	103.74	113.09	28.50
13	.238	4	12.52	39 34	40.84	.30	.29	123.18	132.73	32.06
14	.248	3½	13.50	42.41	43.98	.28	.27	143.18	153.93	36.00
15	.259	3	14.48	45.49	47.12	.26	.25	164.71	176.71	40.60
16	.270	2½	15.45	48 56	50.26	.24	.23	187.66	201.06	45.20
17	.284	2	16.43	51.66	53.40	.23	.22	212.22	226.98	49.90
18	.292	1½	17.41	54.71	56.54	.21	.21	238.22	254.46	54.81
19	.300	1	18.40	57.80	59.69	.20	.20	265.90	283.52	59.47
20	.320	0½	19.36	60.82	62.83	.19	.19	294.37	314.15	66.76
21	.340	0	20.32	63.83	65.97	.18	.18	324.31	346.36	73.40